November 1996 Vol. 20 No. 11

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*The Design/Engineering Technology Digest*

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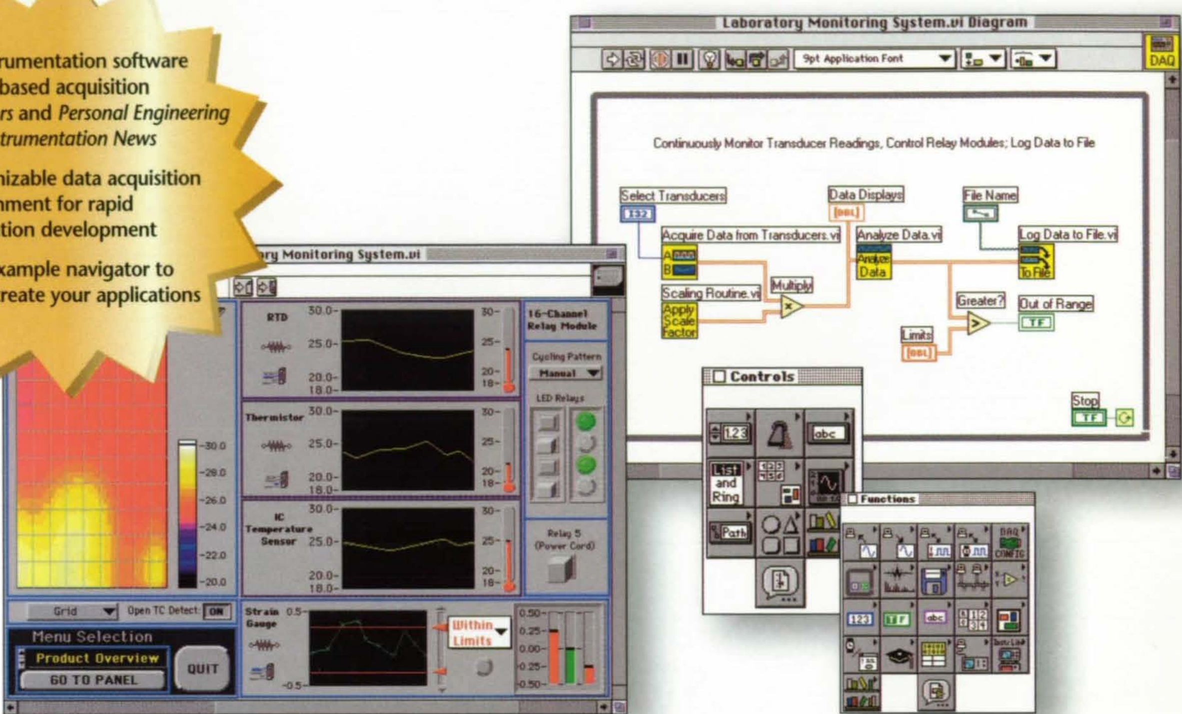


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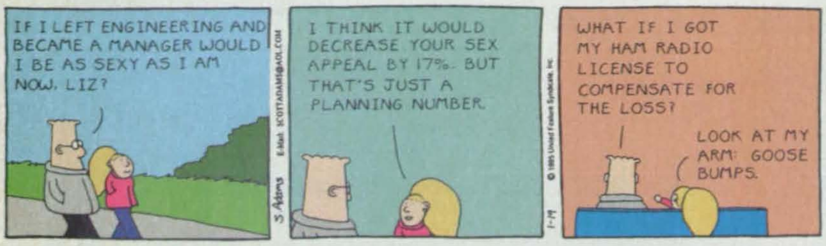


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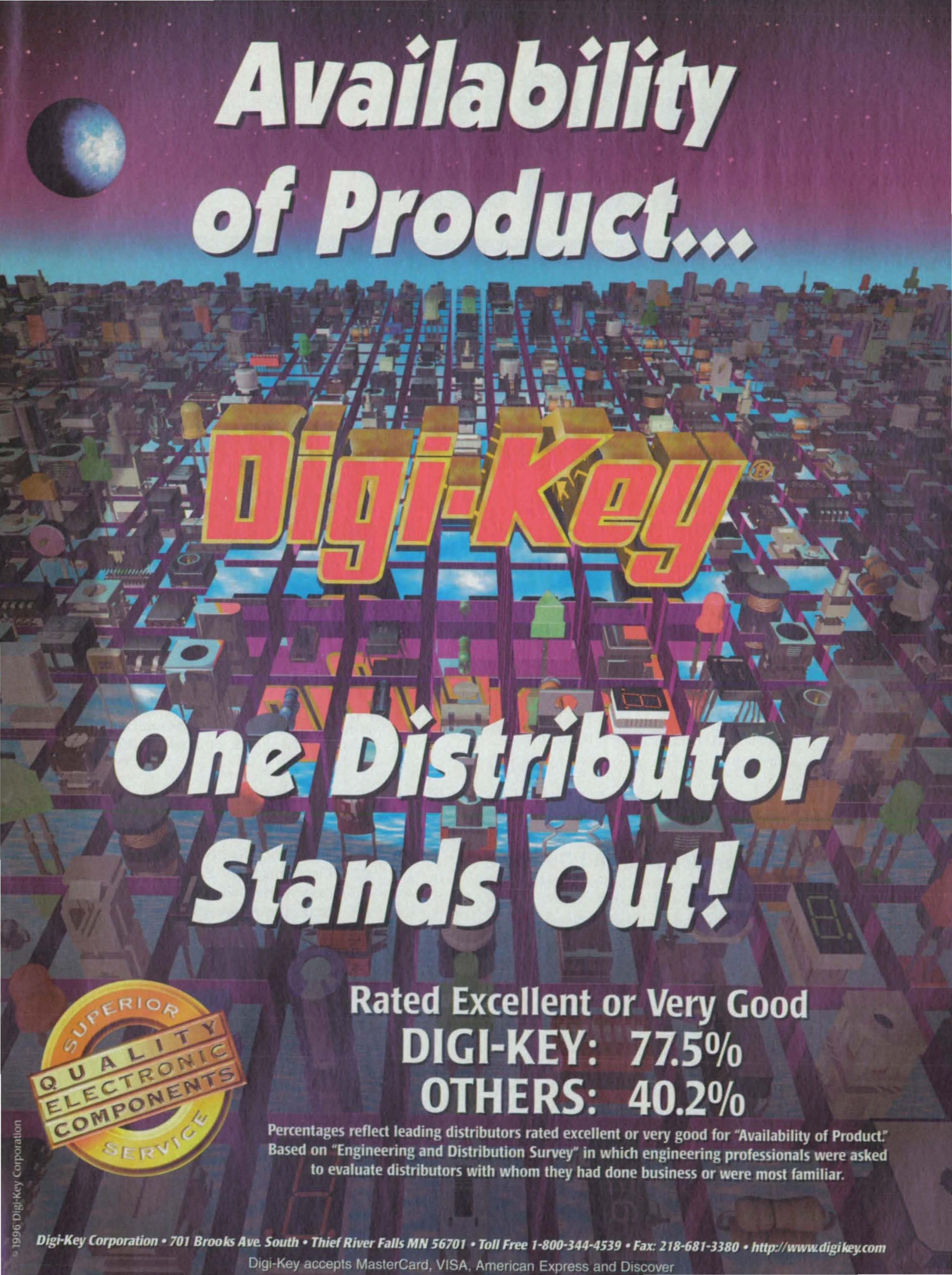
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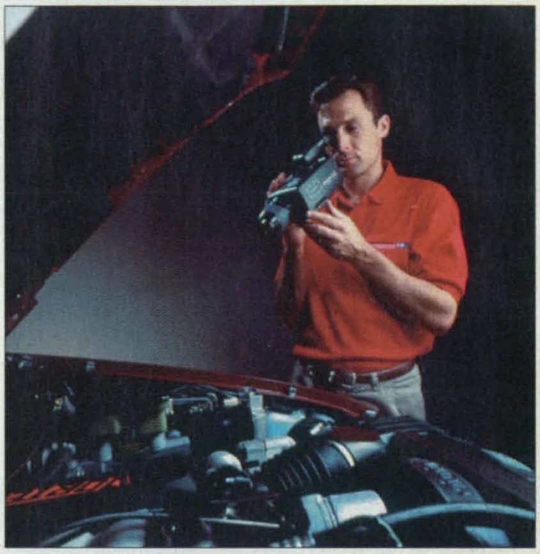

***Video and imaging applications in the scientific, engineering, and research communities range from radar data imaging to robotic vision systems. The Special Focus on Video and Imaging, beginning on page 29, includes these applications, as well as products such as the ThermaCAM™ SC1000 infrared camera from Inframetrics, Billerica, MA.***

Photo courtesy of Inframetrics

## FEATURES



## TECHNICAL SECTION



*(continued on page 8)*

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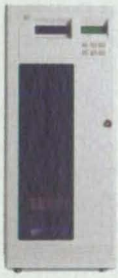

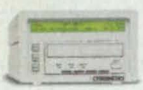

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***On the cover:***

***The BOOM3C™ immersive display from Fakespace, Inc., Mountain View, CA, enables viewing of 3D scientific visualizations and virtual environments in simulations. The device enabled simultaneous display of air flows and temperature gradients in this simulation of a Harrier jet, created in the Virtual Wind Tunnel at NASA's Ames Research Center. For more information on Fakespace and its BOOM technology, see Mission Accomplished on page 26.***

Photo courtesy of Ames Research Center and Fakespace




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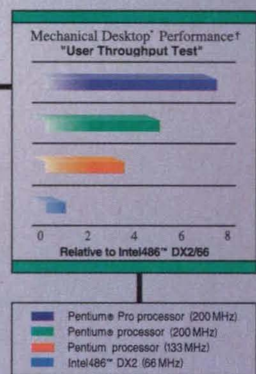


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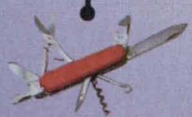

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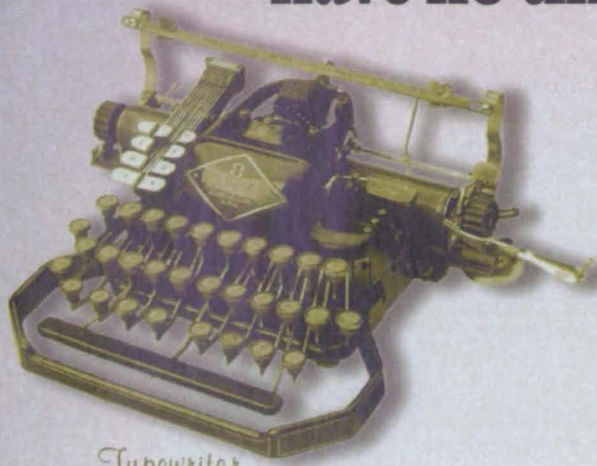
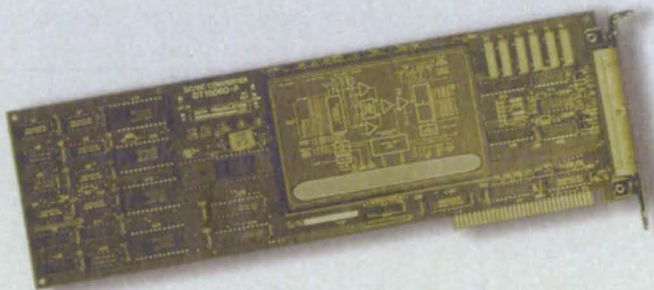
# Serious data acquisition professionals have no time for nostalgia.



Typewriter
c. 1922

Adding Machine
c. 1941

Rotary Telephone
c. 1953



ISA Data Acquisition Board
c. 1984

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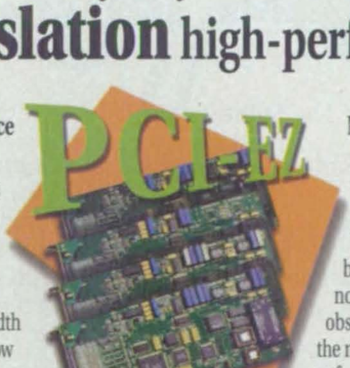


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# Reader Forum

*Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a question regarding a specific technical problem, or if you have an answer to a question that appeared in the September column, send your letter to the address below.*

*Your magazine provides a constant source of innovative ideas applicable across multiple disciplines. However, I would like to see more in the biomedical area, especially concerning adaptive technology for severely handicapped persons.*

Gary Forehand
Miami, FL

*(**Editor's Note:** Gary, please see NASA News Briefs, beginning on page 22, which features a story on how NASA's Langley Research Center and an Ohio-based company co-designed a software program to assist in communicating with severely disabled people.)*

*In the July 1996 issue, you ran an interesting brief entitled, "Magnetic Antennas Using Metallic Glass" (page 50). We have a different application for which metallic glass would be ideal. However, we have been unable to locate a source of metallic glass. We would be grateful for the name and address of a source of metallic glass in small quantities for experimentation and prototyping. Thanks for your help.*

Kermit V. Gray
President
Woods & Waters
Kansas City, MO

*Thank you to Richard Katz of Goddard Space Flight Center for developing the interface circuit described in the brief, "Interface Circuit for Connecting Instruments to Computers" (June 1996, page 36). Our company needed this type of device to use with the Delta III $LH_2 / LO_2$ rocket program to interface our bi-directional cryogenic flow systems and telemetry-monitoring computer.*

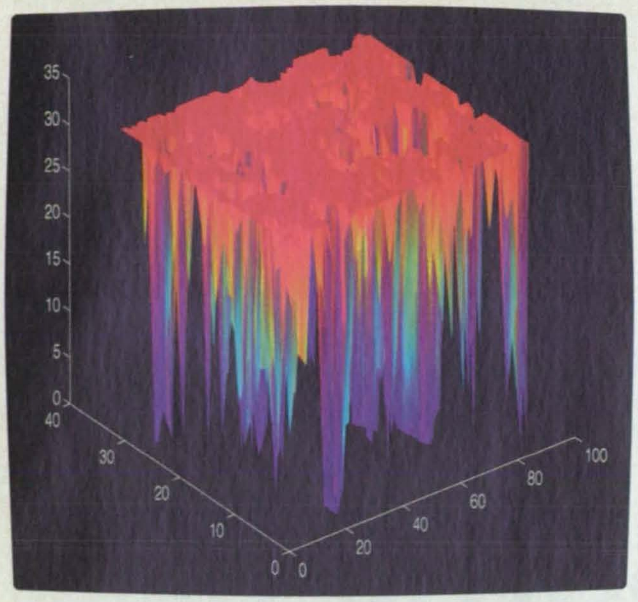
Frederick Liu
President
Quantum Dynamics
Woodland Hills, CA

NASA Tech Briefs *keeps me updated on cutting-edge computer imaging technology. The information I've requested from the brief, "Holographic Imaging in Dense Artificial Fog" (June 1996, page 64) will impact my work on 3D imaging.*

Richard J. Felix
President
Omni General Corp.
Sacramento, CA

**Send your letters to the Editor at:**
Reader Forum, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017.

**Fax:** 212-986-7864; E-mail: ntb_edit@interramp.com
Please include your name, company (if applicable), address, and phone number or E-mail address.




*This surface plot shows impact damage to a rectangular section of helicopter laminate material. Algorithms developed with the MATLAB Neural Network Toolbox classify echoes from ultrasonic signals to automate non-destructive inspection. Data courtesy of McDonnell Douglas under an AATD contract.*

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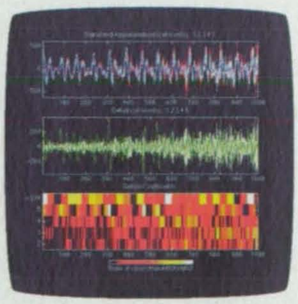

*MATLAB Wavelet Toolbox algorithms perform a 5-level decomposition of a voice signal. Data courtesy U. S. Robotics Mobile Communications Corp.*

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# New Product Ideas

**New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Commercial Technology Office of the sponsoring NASA center (see page 14).**

## Image Sensors With Individual Pixel Reset

A proposed design concept would overcome the limitation of electronic image sensing that results in underexposed and overexposed spots of a scene. Individual pixel reset would adjust those portions and make it possible to see the details that would otherwise be engulfed by those spots.
(See page 34.)

## Stereoscopic Robotic Vision With Multispectral Imagery

Differences in spectral radiances in near infrared are used to distinguish between vegetation and rocks. Use of this spectral aspect in the overall terrain classification scheme is part of the continuing program in the development of a real time robotic-vision system.
(See page 38.)

## Image-Recognition System Determines Orientation of Object

Hybrid digital-electronic/analog optical image-processing systems are being developed to recognize objects from different positions, orientations, and distances. When fully developed, these systems will enable robot arms to recognize and grasp a tool that is moving in any direction at any position or orientation.
(See page 38.)

## Machine-Vision System Maps Surface Flaws

This system identifies surface imperfections in what is supposed to be a smooth planar surface. The system should be useful in mass production where there is a need for quick detection of flaws on machined and polished surfaces.
(See page 41.)

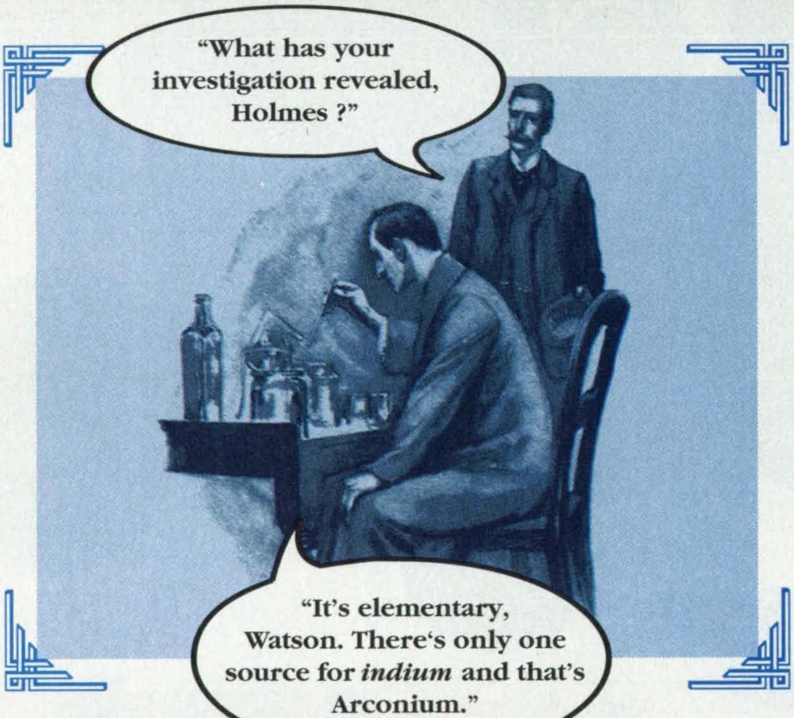
## Current-Measuring Voltage-Follower Circuits

These circuits make it possible to apply the same voltage to a number of proximate loads while isolating the loads from each other so that the currents in the loads can be measured without crosstalk. Application is in capacitive proximity sensors.
(See page 50.)

## Real-Time Controller for a Redundant Robot

A manipulator arm and a mobile platform are controlled in coordinated fashion thanks to this real-time controller. This system was devised for an eight-degree-of-freedom robot.
(See page 54.)





# NASA NEWS BRIEFS

NASA's Ames Research Center is collaborating with the Department of Plastic and Reconstructive Surgery at Stanford University Medical Center in Palo Alto, CA, to develop technology that would allow surgeons to plan complex surgical procedures and visualize the potential results of reconstructive surgery in a virtual environment simulator. The goal is to develop a virtual environment workbench for planning craniofacial reconstructive surgery and training new surgeons using 3D reconstruction and virtual reality.

*Dr. Kevin Montgomery of Ames' Biocomputation Center uses virtual environment equipment as Dr. Muriel Ross looks on. The glove allows manipulation of the image on the monitor and will enable surgeons to "use" surgical instruments to practice surgery on the 3D image. (Photo courtesy of Ames Research Center)*

The technology uses special software that integrates laser images with computer tomography scans of a patient's head, enabling the creation of precise 3D images of the face and skull. The tools also would allow virtual environment simulations of common surgical procedures for use in long-term space missions. The team is especially interested in working with children who need reconstructive surgery to correct deformities of the head and face, and with mastectomy patients requiring breast reconstruction. Using the software, surgeons will be able to "practice" an operation several different ways to see which outcome will be the best.

According to Dr. Muriel Ross, director of the Biocomputation Center at Ames, surgeons will be able to "work on the affected bones as though the surgical manipulations were real." She also said that patients should be better satisfied with the results of surgery. And since the system is interactive, surgeons in other hospitals can collaborate via high-speed networking lines, and new surgeons in remote areas can be trained without having to do actual surgery.

The reconstruction software was developed for space research in NASA's gravitational biology program. It is used, through Space Act Agreements, by more than 20 scientists across the country for a variety of studies, including organization of the retina and embryonic development.

*For more information, contact Ann Hutchison of Ames Research Center at 415-604-4968.*

NASA Ames has teamed with the Bureau of Land Management (BLM), the USDA Forest Service, and the Nevada Division of Forestry (NDF) to examine aerial fire-fighting communications and airspace structures over wildland fires. They are evaluating an electronic Advanced Navigation Display System (ANDS), developed by Ames, to help aerial fire-fighters simplify, standardize, and reduce verbal communications. The evaluation involves recording in-cockpit, air-to-air, and air-to-ground communications, as well as pilot workload information, using mini-cameras installed in the aircraft. Five fire-fighting aircraft based near Reno, NV were outfitted with the audio-video recording capability and the prototype ANDS system.

The ANDS shows the position of other fire-fighting aircraft, establishes an airspace structure graphically on the computer screen, identifies areas needing fire retardant or water drops, and transmits the images to the other aircraft. It uses Pentium-class computers, graphics displays using CD-ROM moving maps, radio modems, and Global Positioning System (GPS) signals. Tests and data collection during actual fire-fighting missions are expected to continue into the 1997 fire season.

*For more information, contact Mike Mewhinney of Ames Research Center at 415-604-3937.*

Adults over 35 years of age are at risk for periodontal disease, the single most destructive dental disease causing tooth loss. The disease involves the loss of connective tissue between teeth, the supporting tissue, and bone. NASA's Langley Research Center and the U.S. Navy are developing an instrument to detect the onset of periodontal disease. It will identify and map the upper boundary of the periodontal ligament and its variation over time as an indicator of the presence of periodontal disease.

Instead of a metal probe being inserted between the tooth and gum, the instrument uses an ultrasonic sound wave to interact with the tooth structure and with the periodontal structures to map the conditions present in the periodontal pocket. The elec-

tronic nature of the instrument allows automatic storage and retrieval of patient data, and the procedure results in minimal-to-no patient discomfort. The technology will expedite the process of identifying periodontal disease, and will provide more comprehensive data from which the physician can diagnose the condition.

*For more information, contact Langley Research Center at 804-864-3293.*

A software program developed for researchers to evaluate the physiological and behavioral effects of flight systems on pilots has been adapted as part of a system to help educators communicate with severely disabled students. NASA's Langley Research Center and Deaton Ashcraft Group of Dayton, OH, have designed a system that records and analyzes how these students react to their environments and communicate their thoughts.

The system is based on Langley's Crew Response Evaluation Window (CREW) software, which was developed to consolidate several human-response monitoring technologies into one computer display window. An evaluator can select and simultaneously view responses to tests involving eye-tracking, physiological stress, and brainwave signal processing while monitoring a pilot in a flight simulator. The software will allow those working with disabled students to measure the children's degree of alertness and whether they are trying to communicate via physical and bio-behavioral states.

Langley is providing DAG with the expertise, hardware, and software necessary to operate CREW as DAG develops a system that combines CREW, biotelemetry physiological monitoring equipment, video equipment, and computer technology. The results may have implications for others with severe disabilities such as traumatic brain injuries, and cerebral vascular diseases.

*For more information, contact Marisol Romero of Langley Research Center at 804-864-5355.*

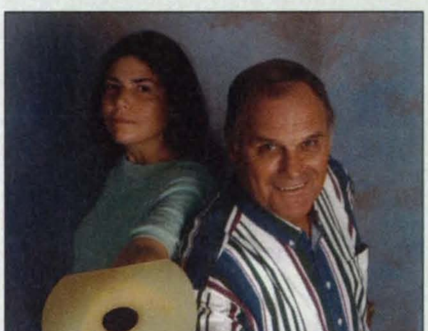
NASA engineers have teamed with the California Department of Forestry and Fire Protection (CDF) to make NASA information technologies available to California firefighters in their efforts to control the state's wildfires. The program involves the use of an ER-2 aircraft to provide fire-fighters in the field with immediate access to real-time imagery using inexpensive, off-the-shelf hardware and the Internet. The aircraft, equipped with sensors that provide imagery in natural color, color infrared, and the thermal region, overflys a target fire at a height of about 60,000 feet. The imagery yields up-to-the-minute information on fire boundaries, hot spots, and fire activity.

The ER-2 is equipped with a Satellite Telemetry and Return Link (STARLink) system that relays information in real time back to anyone with Internet access. On August 22, the aircraft conducted the first successful operational demonstration of the STARLink system when it flew over the Fork fire region near Clear Lake, CA, where an active wildfire had consumed nearly 80,000 acres. CDF personnel were able to view the fire imagery as it was collected, both at their remote Incident Command Center, and at various headquarters and intelligence facilities around the state.

Information about the ER-2 program and the STARLink system are available via the Internet at: http://hawkeye.arc.nasa.gov. The site has a complete record of imagery recorded on the recent flights.

*For more information, contact David Morse of Ames Research Center at 415-604-4724.*

Gem Twist, a gray stallion that will compete for the United States Equestrian Team at the 1996 World Cup show-jumping competition in Switzerland next month, will have NASA behind him – or more accurately, underfoot. Gem Twist has been fitted with magnetic hoof protector pads designed by Linda Hamilton Greenlaw, who contacted NASA's Marshall Space Flight Center's Technology Transfer Office for assistance in developing and marketing her idea. The request was forwarded to Marshall's materials engineer Deborah Dianne Schmidt and materials technician Anthony J. Schaffer, who fabricated and stress-analyzed the cushioning material and magnetic material in the prototype pads at Marshall's Materials and Processes Laboratory. Their analysis led to an optimal configuration for durability of the pad design, and a recommended method to place the magnetic inserts in the hoof pads to prevent material failures caused by stress.



*NASA materials engineer Deborah Dianne Schmidt (left) and materials technician Anthony Schaffer show the prototypes for Power Pads magnetic hoof protectors. The pads' material was tested for fatigue and durability at Marshall Space Flight Center.*

Greenlaw originally designed the pads to support and cushion the impact of walking, running, and jumping on the horse's hooves and legs, similar to sneakers for a human being. Magnets implanted in the pads increase blood circulation in the hooves, reducing the chance for injury. The magnetic material also works with naturally occurring electrical impulses in the horse's nerves to reduce or eliminate pain from hoof injuries. The pads can be used by horses in military operations, police work, or any application that places stress on the horses' hooves and legs. They are being marketed worldwide under the name Power Pads by Equine Enhancement Products of Woburn, MA.

*For more information, contact Marshall Space Flight Center's Technology Transfer Office at 205-544-6539.*

Camping in the wilderness can be a tranquil experience – no electricity, no phones, no contact with civilization. But what if fires erupt in the forest surrounding your campsite? How would you know? Earth Alert may be the answer. Through a joint project, NASA's Goddard Space Flight Center and Scientific and Commercial Systems Corp. (SCSC) of Beltsville, MD have developed the portable system that warns of disasters via a handheld pager device. Engineers at Goddard's Computer Networks & Communications Branch conceived and co-developed the system to broadcast survival information to isolated populations using existing weather and communications satellites.

Earth Alert manually enters and transmits information from weather satellite up-link stations to geostationary altitude, where the satellite system rebroadcasts it back to Earth. A solar-powered, pole-mounted communications repeater ground station receives and broadcasts the message to personal receivers, which produce an audible tone and a visual symbol message. The symbols communicate across language and literary barriers by illustrating hurricanes, floods, fires, and other disasters. The total time needed to broadcast the warning is 15 seconds.

SCSC also has other users in mind for the system, including fisherman, tourists on island resorts, campers, and people who live near chemical plants.

*For more information, contact Goddard's Technology Transfer Office at 301-286-5810.*

During the past several years, virtual reality has made a quantum leap from its beginnings as a futuristic idea from science fiction films to a commonly used display device for applications as varied as knee surgery simulation and aircraft carrier design. One company that helped advance the use of virtual reality in high-tech industries is Fakespace, Inc. of Mountain View, CA. Since building a **telepresence** camera system for the Virtual Environment Workstation (VIEW) project at NASA's Ames Research Center in 1988, the company has developed and installed subsequent versions of the system in a myriad of environments.

As a graduate student at Stanford University in 1988, Mark Bolas worked with NASA Ames' Scott Fisher on the VIEW project, developing a teleoperated motion platform for transmitting sounds and images from remote locations. Known as Molly™, the system panned, tilted, and rolled in real time, matching the user's head movements. Coupled with a stereo viewing device and software, it created the experience of telepresence – the ability to figuratively project oneself into another environment. To establish a working structure for doing business with NASA, Bolas founded Fakespace Labs in 1989. The Molly system was the company's first commercial product.

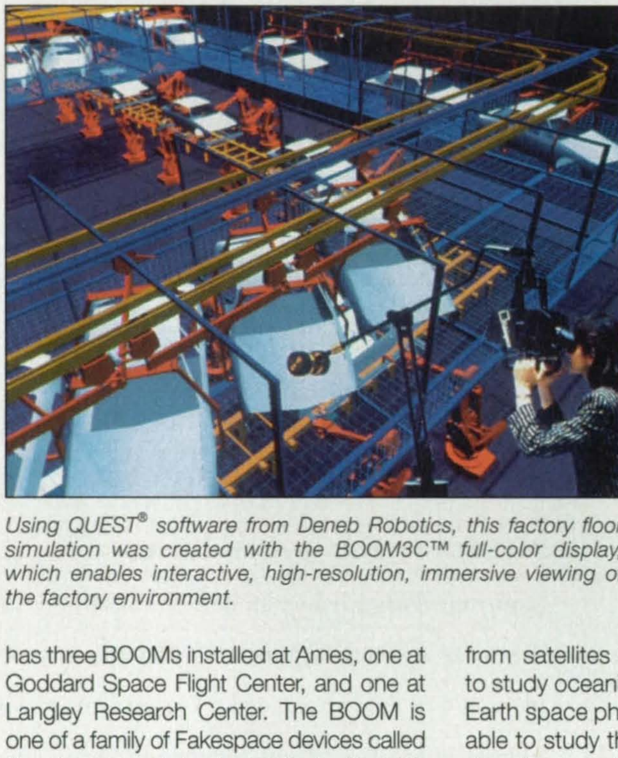
"It wasn't so much the technology we brought from our work at NASA, but the attitude that Scott Fisher and the VIEW project imparted," said Bolas. He viewed the work as a way to solve NASA's problem while also keeping sight of "how exciting this stuff is to work on."

## A BOOM-ing Success

In 1990, Creon Levit of NASA's VIEW Lab contracted with Fakespace Labs to build a stereoscopic viewer to meet the requirements of Ames' Numerical Aerodynamic Simulation (NAS) facility. The system requirements were inspired by the Counterbalanced CRT-based Stereoscopic Viewer (CCSV), an earlier display system designed in the VIEW Lab by Jim Humphreys. Said Bolas, "We looked at the CCSV and saw that virtual reality research facilities really needed something like this. So we set out to build a device that the virtual reality community wanted to use."

The resulting system was the Binocular Omni-Orientation Monitor (BOOM), a stereoscopic viewer perfectly balanced on a six-jointed arm with a six-foot reach. The user holds the viewer by a handle and peers into the eyepieces, which are small CRTs (one for each eye) displaying the 3D virtual environment created by the computer.

Today, said Bolas, the BOOM is the most-used display device for high-end research labs using virtual reality. NASA has three BOOMs installed at Ames, one at Goddard Space Flight Center, and one at Langley Research Center. The BOOM is one of a family of Fakespace devices called "practical immersive technologies," which generate a full range of sounds and sights of a virtual world without the impractical suits, helmets, and headphones usually required in virtual reality applications.



*Using QUEST® software from Deneb Robotics, this factory floor simulation was created with the BOOM3C™ full-color display, which enables interactive, high-resolution, immersive viewing of the factory environment.*

While the BOOM also is used for location-based entertainment and public viewing applications, it originally was designed as a scientific computing and engineering visualization tool. "We're seeing a lot of growth in the engineering community," said Bolas. "With the BOOM, people are able to visualize their designs before they commit to building them. People have said that it's shaved literally years off of their production schedules."

Bolas is quick to point out that although the roots of the company's product line are in virtual reality, Fakespace has never sought to market itself as a virtual reality provider. "We don't think of ourselves as being in the VR industry. We think of ourselves as being in the engineering visualization industry."

Among the growing family of tools that Fakespace provides is the Fakespace Simulation System (FS$^2$), a hands-free or handheld configuration of the BOOM system that allows users to incorporate gloves or other interaction devices for controlling the virtual environment. Prototypes of the latest product, the Immersive WorkBench™, were developed by NASA's Steve Bryson – along with GMD and Stanford University – prior to the joint development of a commercial model by Silicon Graphics and Fakespace. The WorkBench projects 3D imagery over a work table, supporting collaborative groups and easy access to the computer model. Researchers in the Biocomputation Group at NASA Ames purchased one of the first production units.

NASA Goddard uses the BOOM display device to visualize scientific data collected from satellites and software simulations to study oceanic, atmospheric, and near-Earth space phenomenon. Scientists are able to study the El Nino Effect using 3D visualization to show isosurfaces of ocean temperatures in relation to wind vectors at various altitudes.

Lockheed Martin Missiles & Space used a BOOM display to design a simulation system for virtual prototype development in ship design. It allowed Lockheed research scientists to study a simulation of tanks loading onto the ship to see if the ship's design allowed enough room for them to maneuver.

## Beyond Technology

NASA's role in stimulating initial and ongoing work in virtual reality is not lost on Bolas. His continuing ties to NASA go beyond VR technology and product development. "What the Ames VIEW Lab did for me was to transfer a philosophy," said Bolas. "It taught us to keep the excitement of what we were doing in virtual environments, while producing tools that solved a problem."

*For more information, contact Fakespace at 415-688-1940.*

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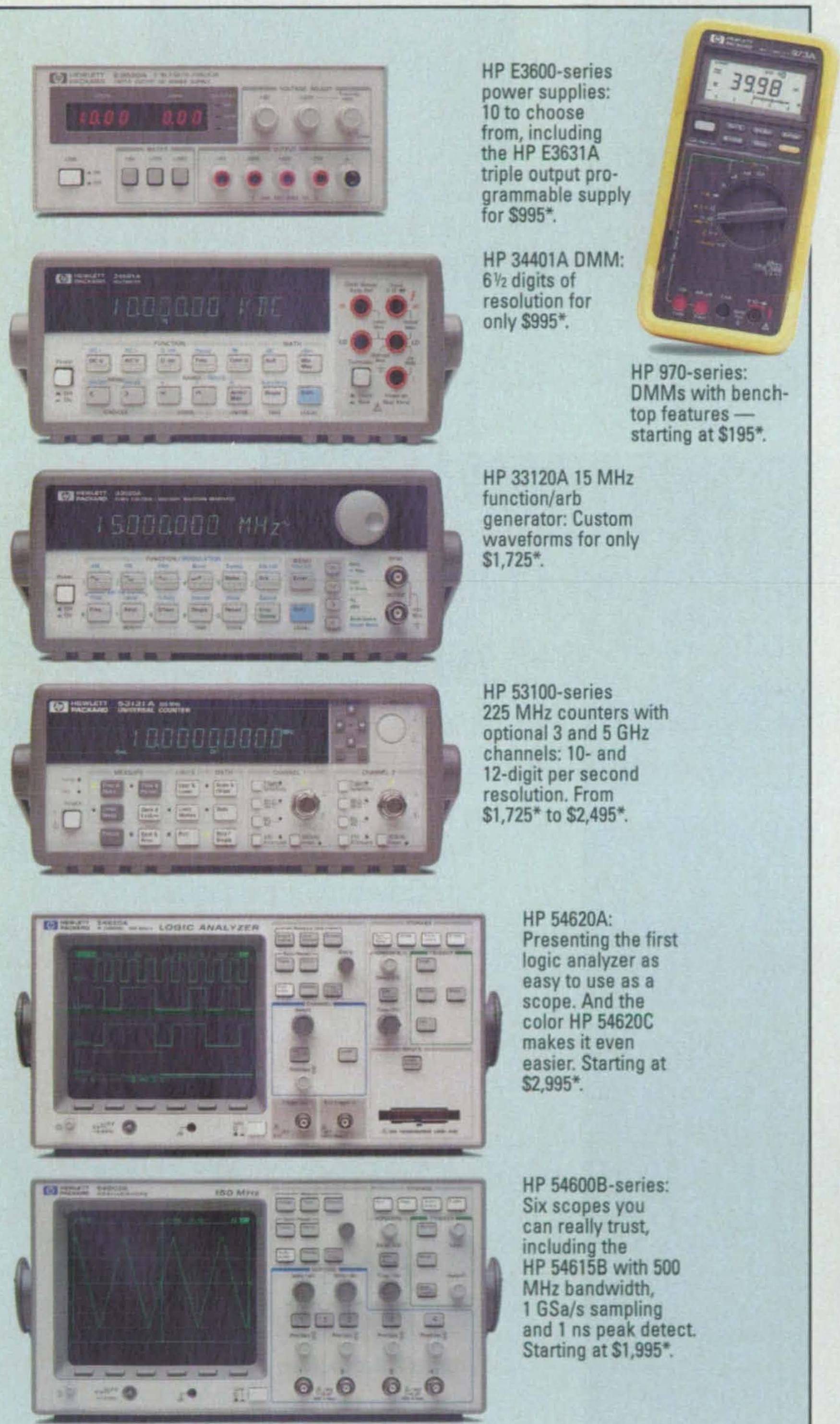

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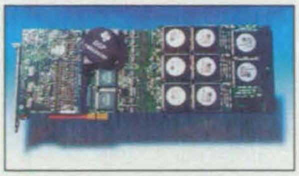



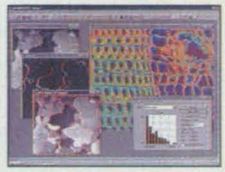

# Demonstration of 15 μm 128 × 128 Quantum Well IR Photodetector Imaging Camera

Advantages would include high uniformity, large two-dimensional focal-plane arrays, low 1/*f* noise, radiation hardness, and low cost.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

First-generation 128 × 128 focal-plane arrays (FPA) of 15-μm wavelength GaAs/AlGaAs quantum-well infrared photodetectors (QWIPs) for staring infrared (IR) sensor systems have been developed. There are several applications that require very-long-wavelength, large, uniform, reproducible, low-cost, low-1/*f*-noise, low-power-dissipation, and radiation-hard IR FPAs. For example, the absorption lines of many gas molecules, such as ozone, water, carbon monoxide, carbon dioxide, and nitrous oxide occur in the wavelength region from 3 to 18 μm. Thus, IR imaging systems that operate in the very-long-wavelength IR (VWIR) region (12 to 18 μm) are also required in many space applications such as monitoring the global atmospheric temperature profiles, relative humidity profiles, cloud characteristics, and the distribution of minor constituents in the atmosphere which are being planned for NASA's Earth Observing System (EOS).

GaAs-based QWIPs are potential candidates for spaceborne VWIR applications and can meet all the requirements mentioned above for this spectral region. By carefully designing the quantum-well structure as well as the coupling of light to the detectors, it is possible to optimize the material to have an optical response in the desired spectral range and determine the shape of the spectral response, as well as reduce the parasitic dark current and therefore increase the detector impedance. Generally, in order to tailor the spectral response of a QWIP to the VWIR spectral region (12 to 20 μm) the barrier height should be lowered and the well width increased, relative to shorter-cutoff-wavelength QWIPs.

The present VWIR focal-plane arrays consist of bound-to-quasi-continuum QWIPs. Samples were grown using molecular-beam epitaxy and their well widths $L_w$ vary from 65 to 75 Å, while barrier widths are approximately constant at $L_b$ = 600 Å. These QWIPs consist of 50 periods of doped ($n_D = 2 \times 10^{17}$ cm$^{3}$) GaAs quantum wells, and undoped $Al_xGa_{1-x}As$ barriers. Very low doping densities were used to minimize the parasitic dark current. The Al molar fraction in the $Al_xGa_{1-x}As$ barriers varies from x = 0.15 to 0.17 (corresponding to cutoff wavelengths of 14.9 to 15.7 μm). These QWIPs have peak wavelengths from 14 to 15.2 μm. The peak quantum efficiency was observed to be 3 percent (lower quantum efficiency is due to the lower well doping density) for a 45° double pass.

Four device structures were grown on 3-in. (7.6-cm) GaAs wafers and each wafer processed into 35 128 × 128 focal-plane arrays as shown in Figure 1. The pitch of the focal plane array is 50 μm and the actual pixel size is 38 × 38 μm$^2$. Two level random reflectors, used to improve coupling of light, can be seen on top of each pixel. These random reflectors, which were etched to a depth of half a peak wavelength in GaAs using reactive-ion etching, had a square profile. These reflectors are covered with Au/Ge and Au (for ohmic contact and reflection), and In bumps are evaporated on top for hybridization with an Si multiplexer. A single QWIP focal-plane array was chosen (cutoff wavelength of this sample is 14.9 μm) and bonded to a Si multiplexer. The focal-plane array was back-illuminated through its flat, thinned substrate. This initial array gave excellent images with 99.9 percent of the pixels working, demonstrating the high yield of GaAs technology. The standard deviation (σ) of the uncorrected photo signal histogram of the 16,384 pixels of the 128 × 128 array is 2.4 percent, which indicates

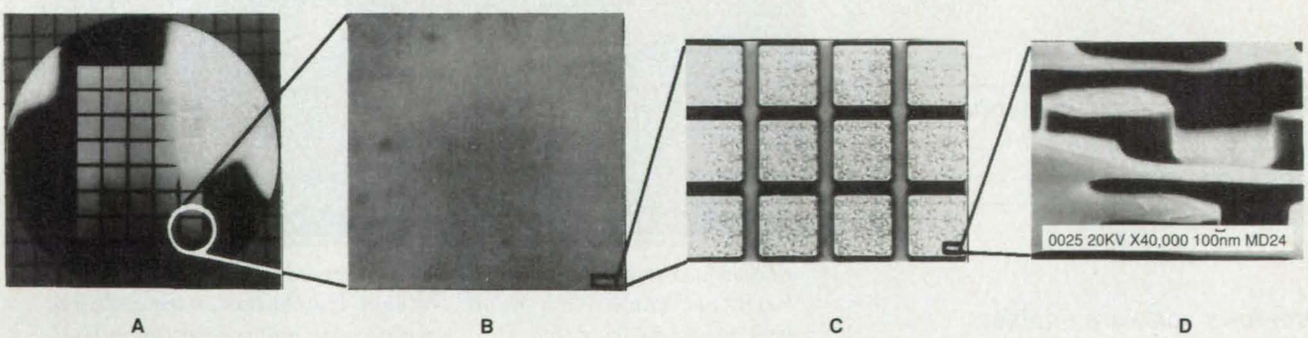


Figure 1. **Thirty-Five 128 × 128 QWIP Focal-Plane Arrays** shown in view (a) were fabricated on a 3-in. (7.6-cm) GaAs wafer. (b) A single 128 × 128 QWIP focal-plane array is shown magnified. (c) Further magnification of a corner of the 128 × 128 QWIP FPA shows two level random reflectors on individual QWIP pixels (38 × 38 μm$^2$). The random reflectors increase the light-coupling efficiency by a factor of eight when the substrate is thinned down to 1 μm. (d) Further magnification of the corner of an individual pixel shows the reactive-ion-etched profile of the random reflector.


For More Information Write In No. 601

the excellent uniformity. As mentioned earlier, this high yield and the excellent uniformity is due to the excellent GaAs growth uniformity and the mature GaAs processing technology.

Video images were taken at various frame rates varying from 50 to 200 Hz with *f*/2.6 KRS-5 optics at temperatures as high as 45 K, using a multiplexer having a charge capacity of $4 \times 10^7$ electrons. However, the total charge capacity was not available during the operation, since the charge storage capacitor was partly filled to provide the high operating bias voltage required by the detectors (i.e., $V_b = -3$ V). Figure 2 shows an image of a man's face with $NE\Delta T = 30$ mK. It should be noted that these initial results are far from optimum. The QWIP device structures were not optimized; the gratings were also not optimized for the maximum light-coupling efficiency; no microlenses were used; no antireflection coatings were used; no substrate thinning was used (in the case of VWIR imaging, the hybrid was thinned to 25 µm, but this was not sufficient to improve the efficiency of coupling of light to small pixels); and finally the multiplexer used was a photovoltaic InSb multiplexer, which is certainly not optimized to supply the proper bias and impedance levels required by photoconductive QWIPs. Implementation of these improvements should significantly enhance the QWIP focal-plane array operating temperatures (i.e., 77 K for 10 µm and 55 K for 15 µm).

Figure 2. This is **One Frame** from a video image obtained with a 15-µm wavelength QWIP. $NE\Delta T = 30$ mK.

*This work was done by Sarath Gunapala, True-Lon Lin, Jin S. Park, and Gabby Sarusi of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 72*** *on the TSP Request Card.*
*NPO-19407*


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# Image Sensors With Individual Pixel Reset

The dynamic range within an image frame would exceed that of other image sensors.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Individual pixel reset has been proposed as a design concept for increasing the dynamic ranges of electronic image sensors. The concept is applicable to integrated-circuit image sensors of various types, and particularly to complementary metal oxide/semiconductor (CMOS) active-pixel sensors of the photodiode and photogate types.

In traditional mechanical shuttering in film photography and in traditional control of integration time in electronic image sensing, all parts of the image are subjected to the same exposure or integration time, respectively. One can increase a spatially averaged dynamic range between image frames by use of different exposure or integration times during different frames, but one cannot increase the dynamic range from place to place within an image frame. Thus, the sensor in some parts of the image could be underexposed (giving rise to black patches in the output image), while the sensor in other parts of the image could be overexposed, causing saturation of the sensor with resultant white patches in the output image.

The proposed individual pixel reset would overcome the limitation of the traditional exposure control described above. The essence of individual pixel reset is to adjust the integration time for each individual pixel by adjusting its reset time according to the local illuminance. By so doing, one could prevent both underexposure (insufficient pixel output) and overexposure (saturation at the maximum pixel output level). In this way, individual pixel reset would make it possible to extract details from portions of images that would otherwise be hidden in black and white underexposure and overexposure patches.

The figure illustrates the circuitry and timing signals for one pixel of a typical photodiode CMOS active-pixel image sensor, both with and without individual pixel reset. In both the traditional and the proposed readout schemes, a "reset" (RST) signal starts the integration period by resetting or precharging the charge-integrating node of the circuit. The end of the integration period for this and all the other pixels in the same row is defined by a "sample" (SMPL) signal, which causes the voltage indicative of the integrated charge to be coupled through a column bus to readout circuitry.

In the traditional readout scheme without individual pixel reset, the same RST signal is applied to all the pixels in a row, so that all pixels have the same integration period. The proposed scheme with individual pixel reset would be similar to the traditional scheme, except that each pixel would be addressable individually by two RST signals; "row reset" (RRST) and "column reset" (CRST). Neither RRST alone nor CRST alone would suffice to reset the pixel. However, when both RRST and CRST were high, a signal called "logical reset" (LRST) would be applied to the pixel reset terminal, starting the integration period. Because each pixel could be addressed by a unique combination of RRST and CRST, it could be reset at any time. Thus, the integration period for a given pixel could be a portion of the maximum integration period, as indicated by $T_1$, $T_2$, or $T_3$ in the figure.

*This work was done by Orly Yadid-Pecht, Bedabrata Pain, and Eric R. Fossum of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 33*** *on the TSP Request Card.*

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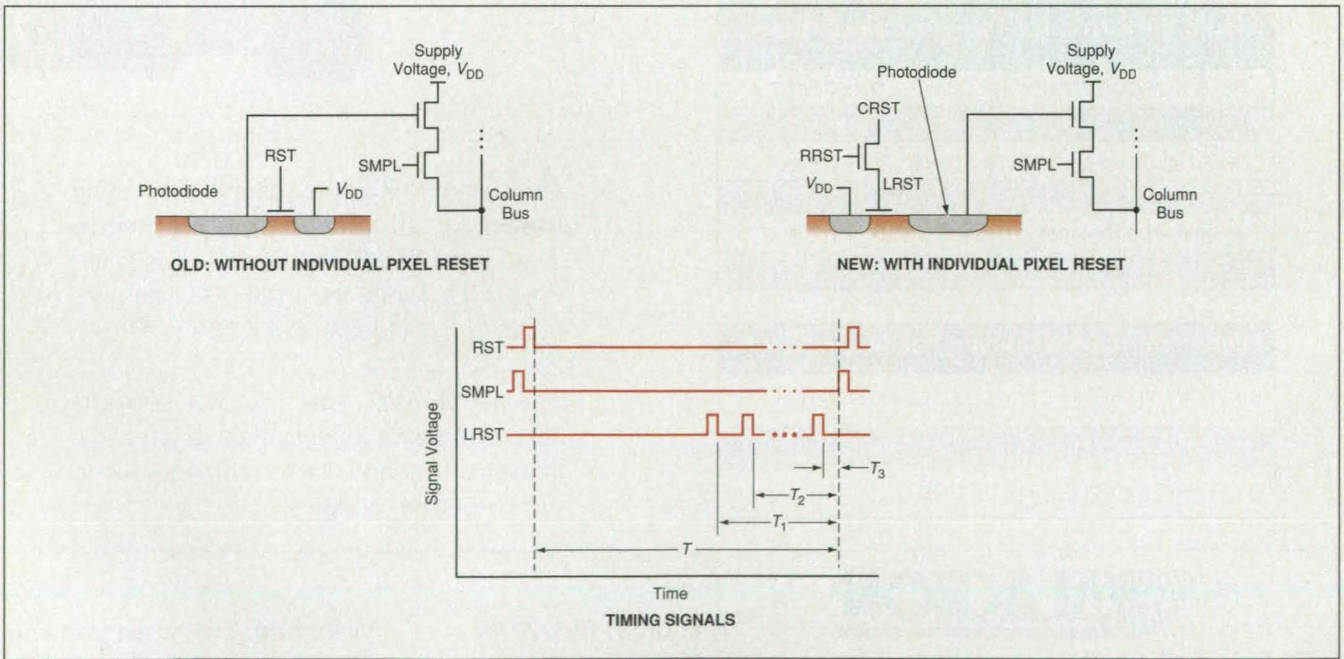



The **Integration Period *T*** starts with the RST pulse in the traditional scheme. In the proposed scheme, $T$ would be a maximum integration period and one could obtain a lesser integration period (e.g., $T_1$, $T_2$, or $T_3$) by addressing the pixel with RRST and CRST to produce the starting signal LRST at the desired starting time.

# Microimaging Spectrometer

This instrument produces spectral reflectance micrographs.

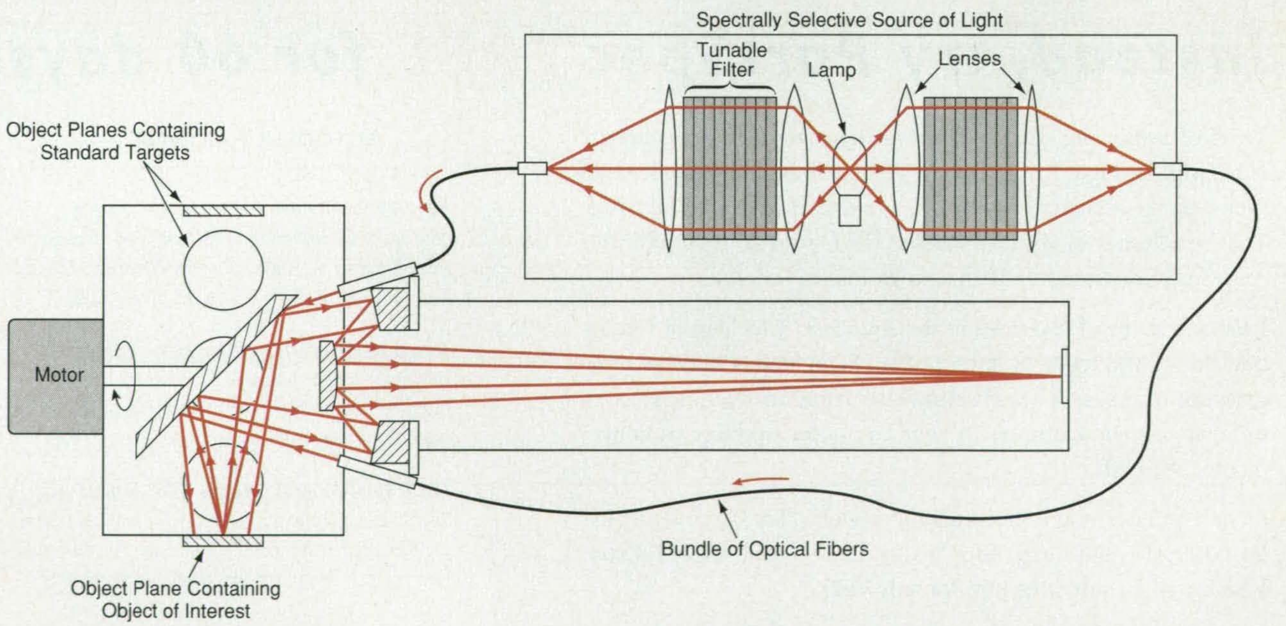
*NASA's Jet Propulsion Laboratory, Pasadena, California*

The microimaging spectrometer is an active-illumination spectral imaging instrument that is essentially an extension of a classical microscope. The instrument can be used in the manner of a classical microscope to view objects in reflectance under illumination at one or more wavelength(s) simultaneously or sequentially. For recording and/or quantitative analysis, the microscope eyepiece can be replaced by an imaging array of photodetectors to generate video micrographs at the selected wavelength(s). The video output can be digitized to enable processing of the spectral reflectance image data.

The figure schematically illustrates the microimaging spectrometer as configured for video imaging under spectral illumination supplied from an external source of light via one or more bundle(s) of optical fibers. In this example, the source of light is a lamp with collimating lenses, condensing lenses, and optical filters that can be tuned to pass the desired wavelength(s). The optical fibers can be terminated at a ring of spots within the instrument and just outside the optical path at the objective end. Thus, the object can be illuminated evenly as though from a ring source directly above it. In an alternative configuration, the optical fibers could be terminated in one spot for oblique illumination to generate shadows for use in three-dimensional surface profilometry. In still other alternative configurations, ring illumination could be provided by light-emitting diodes within the instrument and spaced evenly around the ring, or oblique illumination could be provided by a single light-emitting diode.

The imaging optics are all reflective; this feature eliminates the chromatic aberration that would occur in refractive optics over the broad spectral range (visible and near infrared) in which the instrument is designed to be used. The optics include a flat mirror, at an angle of 45° to the optical axis, that can be turned around the optical axis to direct the view onto one of several object planes located on a circle about the optical axis. The object of interest can be mounted on one of these object planes; standard reflectance, resolution, and color targets can be mounted on the other object planes. This arrangement raises the possibility of frequent automated calibration; it also simplifies calibration in that the object and the standard targets are viewed under the same illumination conditions.

*This work was done by Thomas G. Chrien and Gregory H. Bearman of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 69*** *on the TSP Request Card.* *NPO-19708*




The **Microimaging Spectrometer** is essentially an extension of a classical microscope. Features not usually seen in classical microscopes include spectral illumination via the instrument itself, reflective optics, and provision for switching the view between the object of interest and one or more calibration standard(s).

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| • DC volts | 10nV – 1000V | 1nV – 1100V | 10nV – 1100V | 100nV – 1000V |
| • AC volts | 100nV – 750V | 100nV – 1100V pk | 100nV – 1100V pk | 100nV – 750V |
| • Ohms | 1μΩ – 100MΩ | 100nΩ – 1GΩ | 1μΩ – 1GΩ | 100μΩ – 120MΩ |
| • DC amps | 10nA – 3A | 10pA – 2.1A | 10pA – 2.1A | 10nA – 3A |
| • AC amps | 1μA – 3A | 100pA – 2.1A | 100pA – 2.1A | 1μA – 3A |

# Stereoscopic Robotic Vision With Multispectral Imagery

Spectra are used in classifying obstacles in real time.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A stereoscopic robotic vision system utilizes multispectral imagery in classifying features that appear in images of nearby terrain. The incorporation of this spectral aspect into the overall terrain-classification scheme is one result of a continuing program to develop a robotic-vehicle navigation system that includes a vision system for real-time recognition of obstacles.

The basic real-time terrain-classification and obstacle-avoidance requirements are: (1) to obtain range imagery and use it to detect positive obstacles (rocks) and negative obstacles (ravines); and (2) to distinguish between rocks, which the robotic vehicle must avoid, and bushes, which can be driven over if they are small. The first requirement is satisfied by an advanced stereoscopic robotic-vision system, with enhancements that include rectification (resampling of stereoscopic pairs of images to correct for geometric misalignments and lens aberrations in video cameras) and focus-of-attention algorithms for getting higher spatial resolution at high enough speed. Obstacles are detected by applying slope-detection and related algorithms to each column of each range image. [The use of focus-of-attention and slope-detection algorithms, plus some other aspects of the stereoscopic robotic-vision system at earlier stages of development were described in "Stereoscopic Vision System for Robotic Vehicle" (NPO-18593), *NASA Tech Briefs*, Vol. 17, No. 11 (November 1993), page 72 and "Robotic-Vehicle Perception Control for Detecting Obstacles" (NPO-19079), *NASA Tech Briefs*, Vol. 19, No. 7 (July 1995), page 74.]

The use of multispectral imagery was adopted to satisfy the requirement to distinguish between vegetation and rocks. Multispectral imagery is used for this purpose in remote sensing, but the application to real-time guidance of robots is novel. The basic idea is to exploit the fact that vegetation is bright in near infrared and dark in red, whereas rocks and soil are of medium brightness in both adjacent wavelength regions (see figure). Thus, the presence or absence of vegetation in a given patch of terrain imaged in each of these wavelength bands can be determined by thresholding the ratio between the intensities of light in the two bands. The thresholding is performed in real time, using a table-lookup implementation of the logarithm of the ratio.

*This work was done by Larry H. Matthies and Gregory K. Tharp of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 34*** *on the TSP Request Card.*
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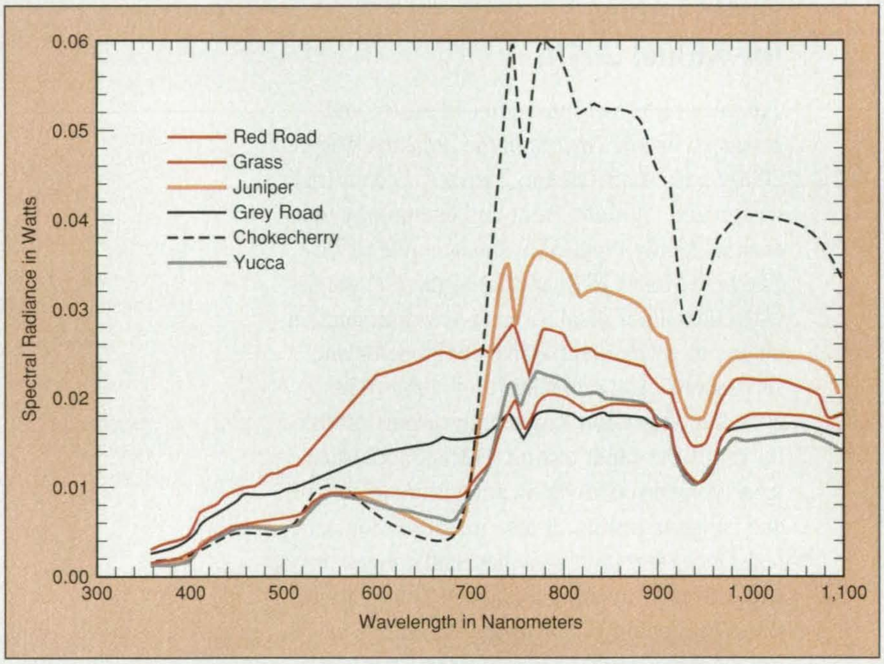


The **Spectral Radiance** of live vegetation in the near infrared generally exceeds that of bare terrain. A robotic vision system can exploit this characteristic to distinguish between rocks and vegetative obstacles.

# Image-Recognition System Determines Orientation of Object

Processing speed is increased by use of a hierarchical set of filters.

*Ames Research Center, Moffett Field, California*

Hybrid digital-electronic/analog optical image-processing systems are being developed to (1) recognize objects depicted at a wide range of positions, scales, and orientations in images and (2) determine those positions, scales, and orientations. Fully developed image-processing systems of this kind are expected to operate in real time and to be incorporated into robotic vision systems; for example, to enable a robot arm to grasp a tool (the object to be recognized) that is moving in any direction at any position or orientation.

An experimental image-processing system of this kind recognizes centered, equal-scale images of an object (the Space Shuttle Orbiter) at various in-plane and out-of-plane orientations and determines in-plane orientations within 5°. Like other image-recognition sys-

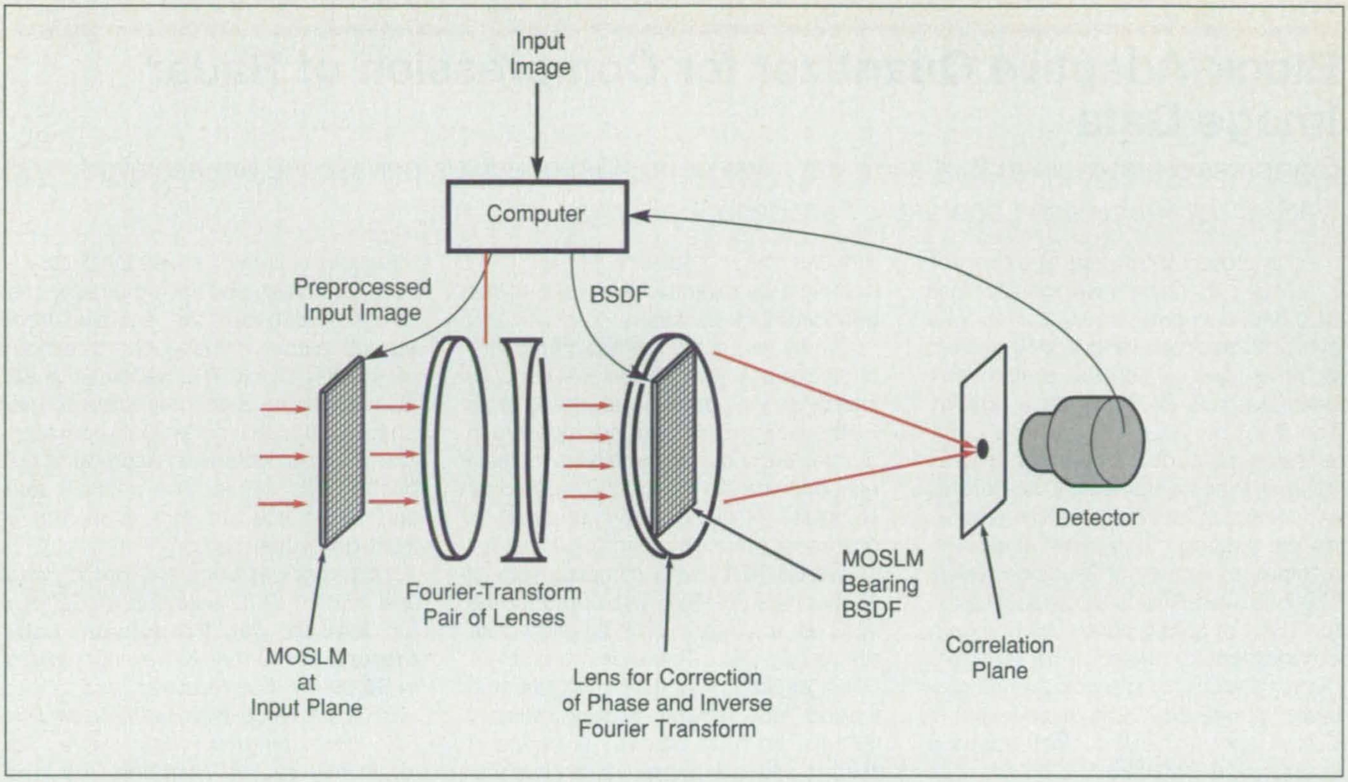


Figure 1. The **Experimental Hybrid Analog Optical/Digital Electronic Image Processing** system combines the speed of optical processing with the generality of digital processing.

tems, this one achieves recognition by computing cross-correlations between the input image and a set of reference or training images that depict the object to be recognized in a large number of poses distributed over the entire range of poses. The advantages of optical processing for computing cross-correlations are that it exploits the Fourier-transform capability of lenses and that it processes the entire image field at once — much faster than is possible with digital electronics at equivalent power levels. The incorporation of an optical correlator (as a special-purpose coprocessor) into a digital image-processing system yields a hybrid system (see Figure 1) that exhibits both the speed of optical processing and the generality of digital electronic processing and thus performs better than does either an optical or a digital electronic system acting alone.

The training-image information is encoded in an optical filter, which is implemented in a magneto-optic spatial light modulator (MOSLM) that is updated digitally. A common problem with correlator-based systems proposed for general image processing is that the filter data base required to account for all possible objects with all possible scales and orientations is prohibitively large and would take an unreasonable amount of time to search, even with the fastest possible optical devices. To decrease the size of the filter data base, the training-image information is encoded in binary synthetic-discriminant-function (BSDF) filters, which are composite binary phase-only filters: each BSDF yields correlations with training images in a number of orientations that span part of the total range. [The construction of synthetic-discriminant-function filters was described in "Modified Synthetic Discriminant-Function Filters" (ARC 12842), *NASA Tech Briefs*, Vol. 16, No. 6 (June 1992), page 43.] To avoid the need to compute all possible correlations and thereby reduce the search time, the BSDF data base is organized into a hierarchical structure (see Figure 2). In a more general system, the search time could be reduced further by use of alternative sensors and processing (e.g., laser ranging or stereoscopic cameras and processing to determine distances and thereby estimate scales).

*This work was done by Max Reid, Paul Ma, and John Downie of* **Ames Research Center.** *For further information,* ***write in 76*** *on the TSP Request Card.*
*ARC-13312*

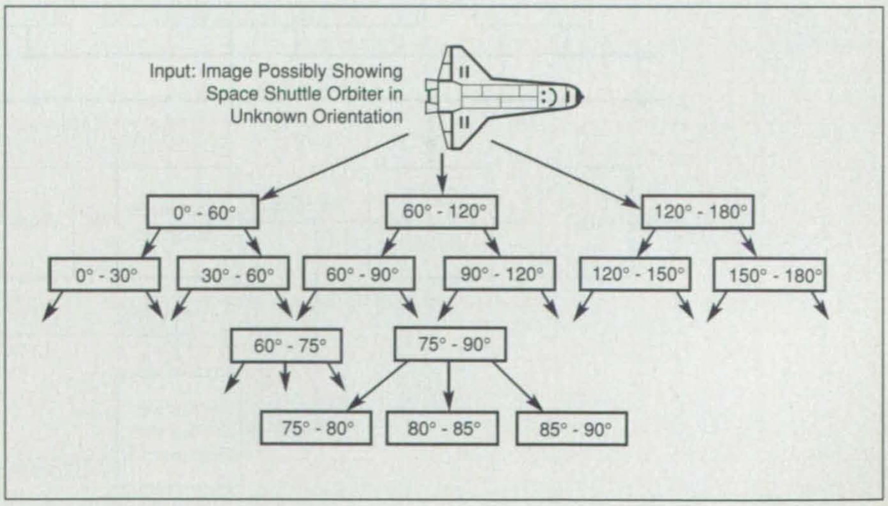


Figure 2. A **Data Base of BSDFs** used in the experimental image-processing system can be used to recognize the Space Shuttle Orbiter and to determine its in-plane orientation within 5°. The data base is arranged hierarchically to speed the search for the correct orientation. (Because the BSDFs are invariant under 180° rotations, this data base covers the full 360° range.)

# Block-Adaptive Quantizer for Compression of Radar Image Data

Compression rates up to 8 at sampling rates up to 30 megapixels per second are achieved.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

An improved block-adaptive quantizer (BAQ) has been developed for use as a data-compression subsystem of a synthetic-aperture-radar (SAR) system or other remote sensing system that generates an SAR-like data stream. The BAQ provides a selectable compression ratio of 8, 4, 2, or bypass (ratio of 1; no compression). It operates at a sampling rate of up to 30 megapixels per second in real time, albeit with a "pipeline" latency of 32 clock cycles. The improved BAQ is a compact unit in the form of a low-power, high-speed, complementary metal oxide/semiconductor (CMOS), single-chip, very-large-scale integrated (VLSI) circuit with a design specific to the block-adaptive quantization algorithm.

This BAQ encodes the raw SAR data by use of thresholds generated from the current burst instead of from the previous burst as in the BAQ for the Magellan Venus SAR. In comparison with the previous-burst approach, the current-burst approach offers the advantage that it alleviates the degradation of performance in the progression from single-beam to advanced multiple-beam SAR imaging; it also reduces the complexity of the BAQ hardware by minimizing the size of the encoding look-up table.

The figure shows the basic functional blocks of the improved BAQ and its interfaces with other subsystems of an SAR system. SAR data are received in bursts, each burst containing multiple echoes. The sequence of radar data samples ($\{X(t)\}$, where $t$ is time) is processed through an analog-to-digital converter (ADC) at a sampling rate of as much as 30 MHz. The output of the ADC is a stream of 8-bit sign-and-magnitude data. These data are selectively packed into 16-bit words and loaded into random-access memory (RAM). The RAM buffers the bursts of data to alleviate the real-time processing requirement for an adaptive threshold estimator. The buffered data from each burst are partitioned in $N_e$ echoes. The data in each echo are partitioned into $N_b$ blocks, each containing $N_s$ samples. The $l$th sample in the $k$th block in the $j$th echo of a given burst is denoted $X(l + kN_s, j)$.

After the data from a burst have been loaded into the buffer, the BAQ reads the data and the adaptive-threshold estimator in the BAQ calculates the thresholds from the data. The quantizer encodes the samples from the $k$th block whenever the threshold of the $k$th block $TH_k$ becomes available. Encoding is accomplished by use of an optimized code look-up table. The encoded data from each burst are packed into words. The packed data and thresholds are then stored in a flight-computer memory.

*This work was done by Wai-Chi Fang and William T. K. Johnson of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 98*** *on the TSP Request Card.*

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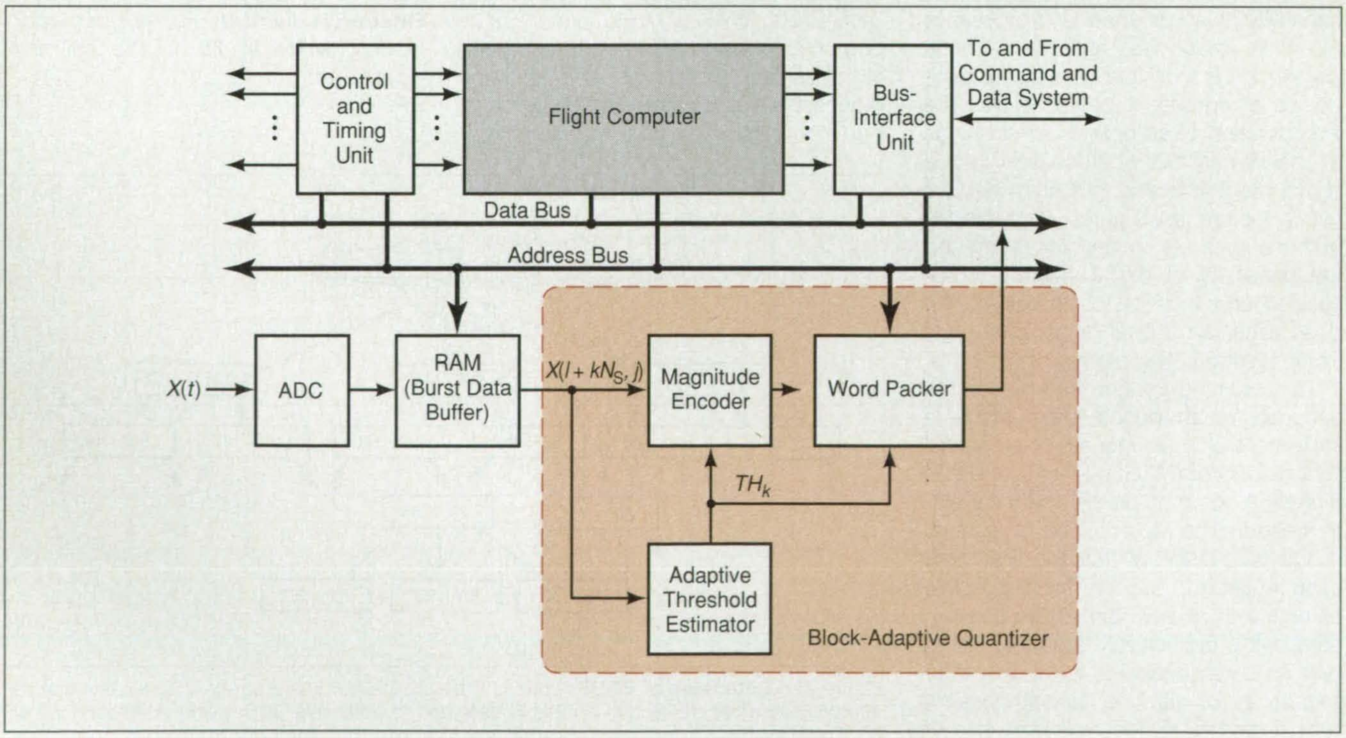



The Improved **Block-Adaptive Quantizer** is a data-compression subsystem of an SAR data system.

# Machine-Vision System Maps Surface Flaws

Bright spots that signify fretting are recognized by an image-processing subsystem.

*Marshall Space Flight Center, Alabama*

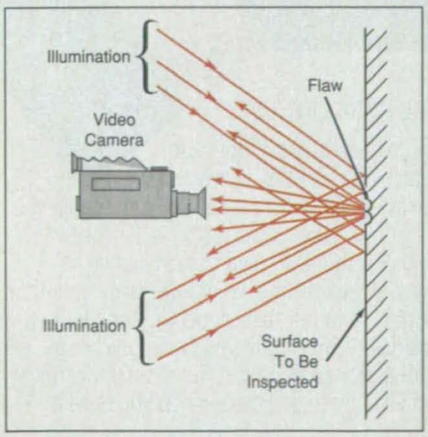
A machine-vision system maps surface flaws generated in fretting of a metal panel or other structural components. The flaws include pits, gouges, scratches, small protuberances, and other features that deviate from the otherwise smooth or planar surfaces. The machine-vision system should be useful in many mass-production situations in which there is a need for quick and accurate detection of flaws on machined, polished, and otherwise smooth surfaces.

The machine-vision system includes a black-and-white video camera aimed perpendicularly to the surface to be inspected. The surface is illuminated, from opposite sides of the line of sight of the camera, by two rectangular, woven fiber-optic panels that provide evenly distributed light that is semicollimated and incident in two planes at acute angles (typically, 50°) from the surface (see figure). The camera and the sources of light are mounted on a robotic manipulator that scans them across the surface, stopping at inspection locations that are selected consistently with inspection requirements and with the dimensions of the field of view of the camera. The image data acquired by the camera and the position data generated by the robotic manipulator are digitized and sent to a desktop computer for processing.

The relatively smooth unflawed portion of the inspected surface reflects the illumination away from the line of sight of the camera. Because flaws reflect and diffract the illumination, they appear as bright spots in the video image. The brightness of a pixel is digitized on a gray scale of 0 (black) to 255 (white). In processing, the image data are first Fourier-transformed to filter out background information. Next, each pixel is binarized by setting its value equal to 0 if its gray level is ≤ 32 or to 1 if its gray level is > 32. The binarized pixel values, taken together with the pixel-coordinate information, and the position data from the manipulator, constitute the data for a primitive binary map of flaws on the surface.

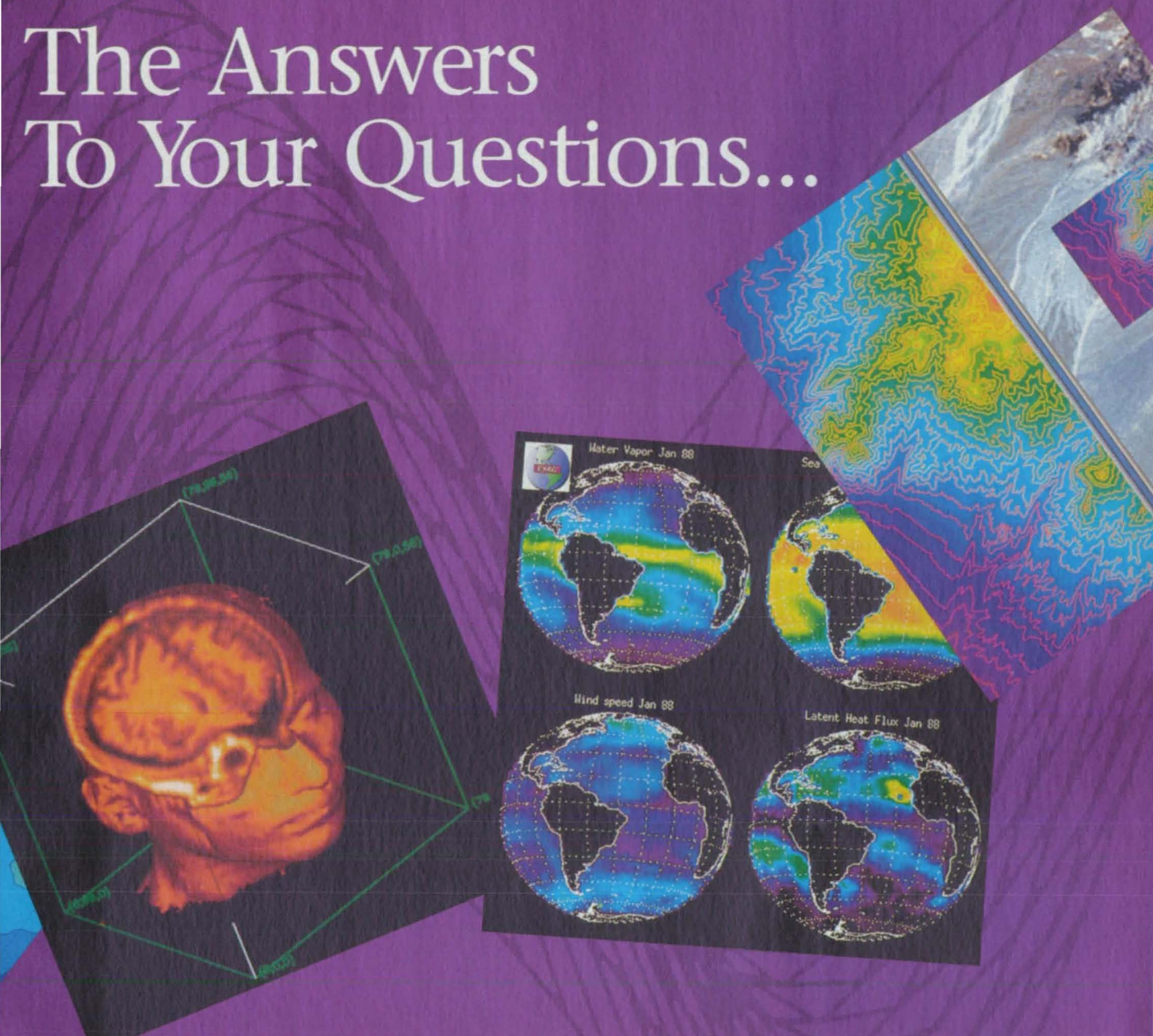
*This work was done by Mark Mueller of Thiokol Corp. for* **Marshall Space Flight Center**. *For further information,* ***write in 37*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-28850.*




**Surface Flaws Scatter Illumination** into the field of view of the video camera, while smooth, unflawed parts of the surface do not. Thus, the flaws appear as bright spots in the video image.

# The Answers To Your Questions...

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# Video and Imaging

StudioZ Producer **video and simulation hardware and software** from Intergraph Computer Systems, Huntsville, AL, allows capture of live video and audio clips from a variety of sources, combines them with 2D graphics or 3D simulations, and outputs the production in real-time video. The system includes a video I/O board with ports for composite and S-video equipment, a JPEG compression board, a 2 Gb audio/visual disk drive, and software.

The system allows computer simulations to be recorded directly from the A/V disk to a videotape recorder in real time and at full frame sizes and field rates. It is compatible with ModelView, MicroStation, and other Windows NT applications.

**For More Information Write In No. 744**

Cincinnati Electronics Corp., Mason, OH, offers the TVS-100 **thermal video system** for predictive and preventive maintenance. The system incorporates a portable camera for temperature measurement and analysis at three movable points in a range from -10° C to 950° C. It provides an alarm feature for maximum temperature range settings based on a specific point or predetermined area. Alarms may be audible or flashing lights. Additional functions are triggered by external voltage outputs.

Other features include disk storage of 30 images, a 4" color LCD monitor, and 12-bit dynamic range. Optional CE Image + Windows software provides standard and custom report generation and advanced analysis. Applications include locating faulty electrical circuits, inspecting printed circuit boards, checking molding equipment, and determining heat patterns.

**For More Information Write In No. 746**

The PanelMount 16.1" **flat-panel display** from Dolch Computer Systems, Fremont, CA, enables industrial engineers and system integrators to display information for viewing by several people simultaneously. It allows data to be instantly readable from a distance in medical, aerospace, and automation control applications. The plug-and-play color monitor has a diagonal active matrix thin film transistor viewing area that offers up to 1280 x 1024 resolution and 262,000 colors.

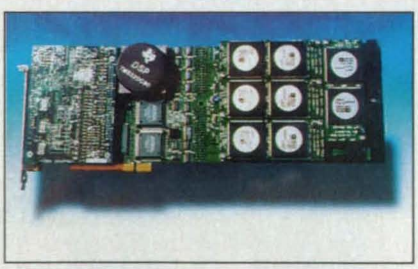
The monitor is sealed in steel with a clear polycarbonate shield, which protects against dust, water, and dirt contamination. Flush-mounting allows the 3"-deep display to be integrated into control panels and workstations. It features a contrast ratio of 100:1, which allows viewing from extreme angles. Pricing starts at less than $9000 each in quantity.

**For More Information Write In No. 747**


Colorado Video, Boulder, CO, offers the Model 307 **video caliper,** which provides the means to take horizontal measurements of objects in a real-time video image. The LCD display indicates the distance between two cursors that are positioned around the object to be measured. Three different scale calibrations can be set and selected as required.

The caliper superimposes two vertical cursors onto a video display. The user adjusts the position of the cursors using front-panel controls – the right control sets the distance between the cursors by moving the right cursor only; the left control moves both cursors across the screen while maintaining the distance between them. Three scale adjustment controls calibrate the meter reading for a given distance. A switch allows the user to select among the three control settings.

**For More Information Write In No. 749**



The FT-IP **integrated imaging platform** for PC and VME bus computers from Alacron, Nashua, NH, is optimized for high data-rate, compute-intensive, real-time imaging applications. It is designed for customization to meet most image acquisition and processing requirements. The platform can be configured with a variety of tightly coupled on-board digital and analog framegrabbers supporting many input formats and resolutions.

The board incorporates a 2 GigaOp processor and a buffered DMA local memory architecture with up to 8 Mb of local synchronous DRAM. A separate I960 control processor allows image processing to be performed continuously at full speed. It supports up to 256 Mb of on-board global DRAM. For real-time pattern recognition and classification, the board provides a scaleable array of up to 8 ADSP 2106x SHARC processors with an additional GigaFLOP of power.

**For More Information Write In No. 750**


Mercury Computer Systems, Chelmsford, MA, offers the MDVS-1200R **digital video server,** which provides expandable, real-time video editing for multiple suites of digital editors. It features a standards-based hardware platform with a JAVA-based application suite. The server provides a centralized file server and network connectivity for browsing, media storage, and editing functions.

Editing suites can be connected to a shared storage facility, eliminating the need for standalone workstations. The system is combined with the Media 100® digital video system from Multimedia Group.

**For More Information Write In No. 751**

# Video and Imaging

Ascension Technology Corp., Burlington, VT, has introduced MotionStar Wireless™ **magnetic motion tracker**, which captures human motions in real time. It uses pulsed DC magnetic fields emitted by a long-range transmitter to track the position and orientation of each sensor over 100 times per second. The range extends over a 20-foot diameter with the transmitter in the center. Up to 14 sensors may be mounted at key points on a human subject.

Inputs from the sensors travel via cables to a miniaturized, battery-powered electronics unit mounted in a belt pack. Sensor data and other signals from body-mounted peripherals such as gloves are sent to a base station for processing. The outputs are transmitted to the user's host computer via serial or ethernet interface. Three-dimensional computer images are available instantly on-screen.

**For More Information Write In No. 740**

Data Translation, Marlboro, MA, offers the DT3157 MACH™ **frame grabber** PCI image capture board for digital cameras. As a PCI Bus Master, the system can transfer images in real time to system memory or display, eliminating the need for on-board memory and graphics. It is compatible with single- and dual-channel digital cameras with image size outputs to 4 Mb and data rates to 40 Mb/second. It accepts 8, 10, 12, 14, and 16-bit digital images with pixel clock rates to 20 MHz on a single channel and up to 40 MHz on dual 8-bit channels.

The frame grabber is connected to cameras via a modified 68-pin connector. For use with cameras that do not use the 68-pin connector, optional interface cables are available. The system is Microsoft Windows Plug 'n Play compatible and includes a selection of 32-bit Windows example programs. The frame grabber and example programs are priced together at $1495.

**For More Information Write In No. 742**


The SuperView 1000 **video windowing system** from RGB Spectrum, Alameda, CA, displays multiple live video images on a single screen. Video input signals may be NTSC, PAL, or S-Video, and the display screen may be any monitor or data display projector up to 1600 x 1280 pixel resolution. The system comes configured for four- or six- video display; however, up to 24 live video windows can be viewed simultaneously.

The system can be used with the screen displaying only video windows or with a computer screen in the background. When used with a computer, it is compatible with systems up to 1600 x 1280 pixel resolution; when used to display video only, it generates a scan rate output signal up to 1600 x 1280 pixel resolution. Windows can be positioned independently, scaled to any size up to full screen, overlaid with computer graphics, and overlapped with other windows.

**For More Information Write In No. 741**

Inframetrics, North Billerica, MA, offers the SC1000 Therma CAM™ handheld focal plane array **thermal imager** for scientific infrared imaging and temperature analysis. The imager features full-screen temperature measurement accuracy of ±2% or 2° C. The system can operate continuously from a single standard video recorder battery for more than two hours. An optional battery belt is available, which will run the camera for 12 hours.

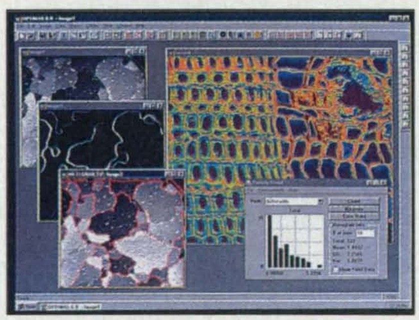
Features include a color viewfinder; an optional 4" color LCD is also available. A serial remote control port for remote control and focus from a PC or handheld controller is standard. FLASH PCMCIA compatibility allows storage of up to 256 images on a single card. To accommodate various target sizes and distances, a number of spectral filters is available for measurements to 2000° C.

**For More Information Write In No. 745**


Datatape, Monrovia, CA, has introduced the AVR-1000 **airborne video recorder** for airborne infrared and black and white video imaging applications. The recorder delivers image recording at 1000 TV line resolution and provides recording bandwidth of 12 MHz. It features a video signal-to-noise ratio of -40 dB and a digital time-base corrector for airborne playback.

The recorder provides one video channel for infrared or black and white video imaging, as well as three auxiliary channels: two 80-Hz to 60-kHz channels and one 200-Hz to 20-kHz longitudinal channel. It uses VHS ST-120 cassette tapes for more than 40 minutes of record time per tape. The lightweight, ruggedized design conforms to MIL-E-5400 Class-1 environment specifications.

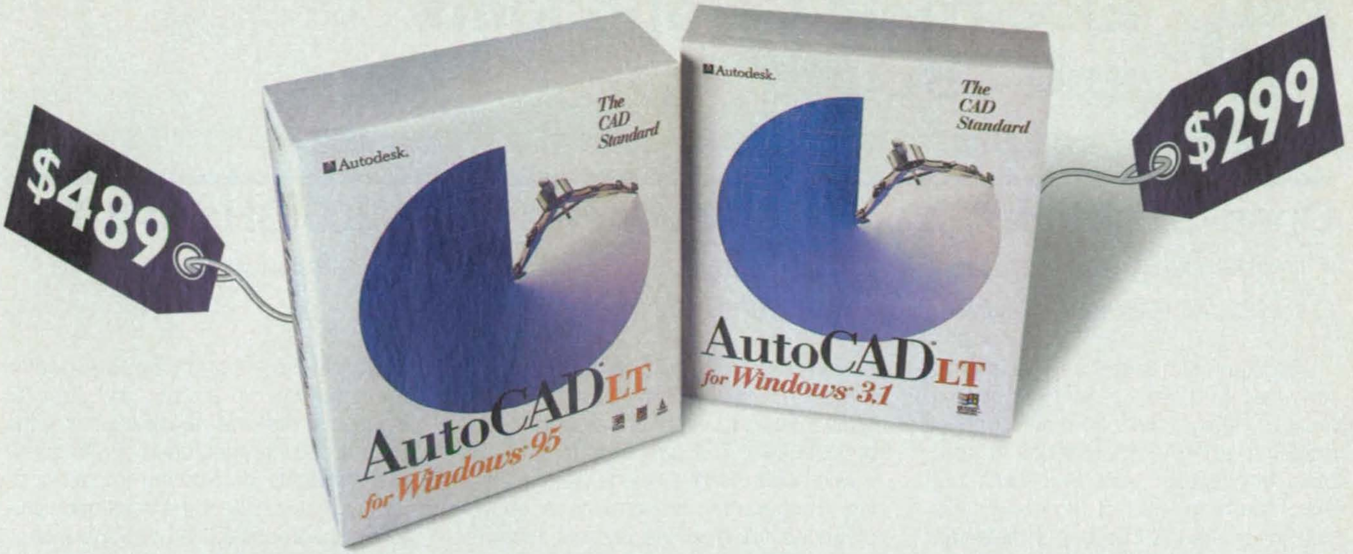
**For More Information Write In No. 743**



Optimas Corp., Bothell, WA, has announced OPTIMAS 6 **image analysis software**, which enables users to solve high-volume image analysis problems using a PC running Windows 95. The 32-bit program performs image processing and measurement functions using new image filters, morphological techniques, automatic multiphase thresholding, and computationally intensive measurements.

Users can record a multi-step image analysis process as a macro, then drag and drop the macro onto a tool in the user-defined toolbar. The macro can then be launched by clicking on the tool. The software supports an image gallery and archiving to Optimas Library™ database software. It supports 32-bit drivers for new, PCI-bus frame grabbers, and maintains support for users of 16-bit image capture devices.

**For More Information Write In No. 748**

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# Electronic Components and Circuits

## Open-Structure Mixer for Frequencies From 200 GHz to 3 THz

A flexible design accommodates variations to suit applications at various frequencies.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

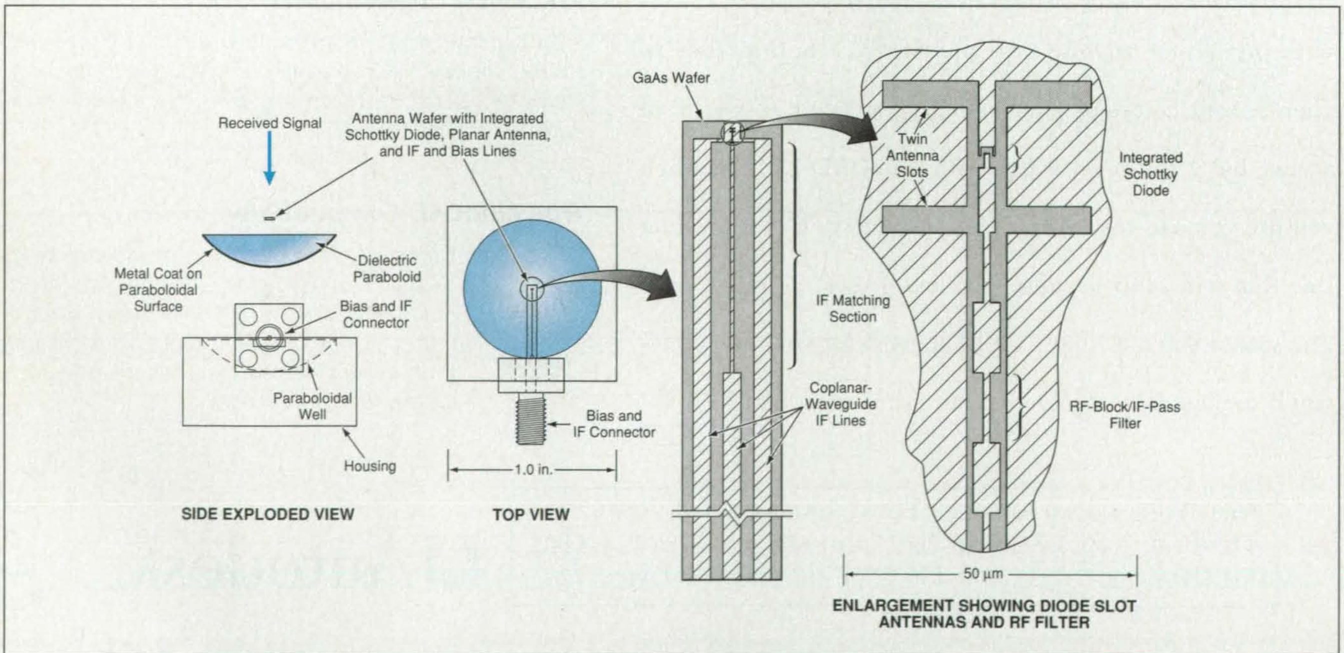
The figure illustrates a novel millimeter-wave heterodyne receiver with a flexible design that can be adapted readily to specific applications at operating frequencies from 200 GHz to 3 THz. The receiver is of the open-structure-mixer type; it includes a dielectric-filled paraboloidal reflector, with radio-frequency (RF), intermediate-frequency (IF), and bias integrated circuitry residing on a small GaAs-based integrated-circuit wafer at the focal plane of the paraboloid. This open-structure mixer design incorporates several improvements over a similar design reported previously in "Open-Structure Mixer for Detection of Hydroxyl" (NPO-19267) *NASA Tech Briefs*, Vol. 20, No. 2 (February 1996), page 30.

Whereas the dielectric filling in the paraboloid in the previously reported receiver was quartz, in the present receiver, the paraboloid is filled with high-resistivity silicon. This is an advantage for the following reasons. In fabricating the previously reported receiver, it was necessary to thin the GaAs integrated circuit to a few microns and transfer it (by a liftoff technique) to a quartz wafer, to which it was bonded by an adhesive. The quartz wafer, in turn, was mounted on the quartz dielectric filling. Because the permittivity of silicon dielectric filling in the present receiver nearly matches that of GaAs, the GaAs integrated-circuit wafer in the present receiver can be fabricated in any thickness convenient for handling and glued directly onto the silicon dielectric filling, without loss of radiation efficiency. Thus, fabrication is simplified.

Device yield in production is greatly increased over that of older designs because the same fixed-size GaAs chip outline can be used for all frequencies, and many chips can be fabricated from a single GaAs wafer. The design accommodates a wide range of wafer thicknesses and is not restricted to ultrathin or difficult-to-handle substrates, even at the highest operating frequencies.

The mixer integrated circuitry includes a planar GaAs Schottky diode at the center of a pair of resonant slot antennas formed together on the GaAs wafer. The antennas are spaced and sized to provide a resistive termination to the diode at the intended operating frequencies. Available terminating impedances of 30, 50, and 100 ohms have been verified experimentally. A coplanar-waveguide RF-block/IF-pass filter is incorporated to simplify the removal of the downconverted mixer product, with matching at both the IF and RF, and with dc biasing of the diode. Because the overall chip size is the same for all frequencies, the operating frequencies can be changed by simply replacing the antenna/diode wafer with another one designed for the new frequencies. The width of the received radiation beam depends on the diameter of the silicon paraboloid; almost any *f*-number greater than 5 can be realized.

*This work was done by Peter H. Siegel of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 35*** *on the TSP Request Card. NPO-19371*




This **Millimeter-Wave Heterodyne Receiver** incorporates improvements over one reported previously in *NASA Tech Briefs*. In this receiver, as in the previous one, mixer components that handle RF and IF signals are necessarily microscopic because of the wavelengths involved and are therefore fabricated together in an integrated circuit.

# Current-Measuring Voltage-Follower Circuits

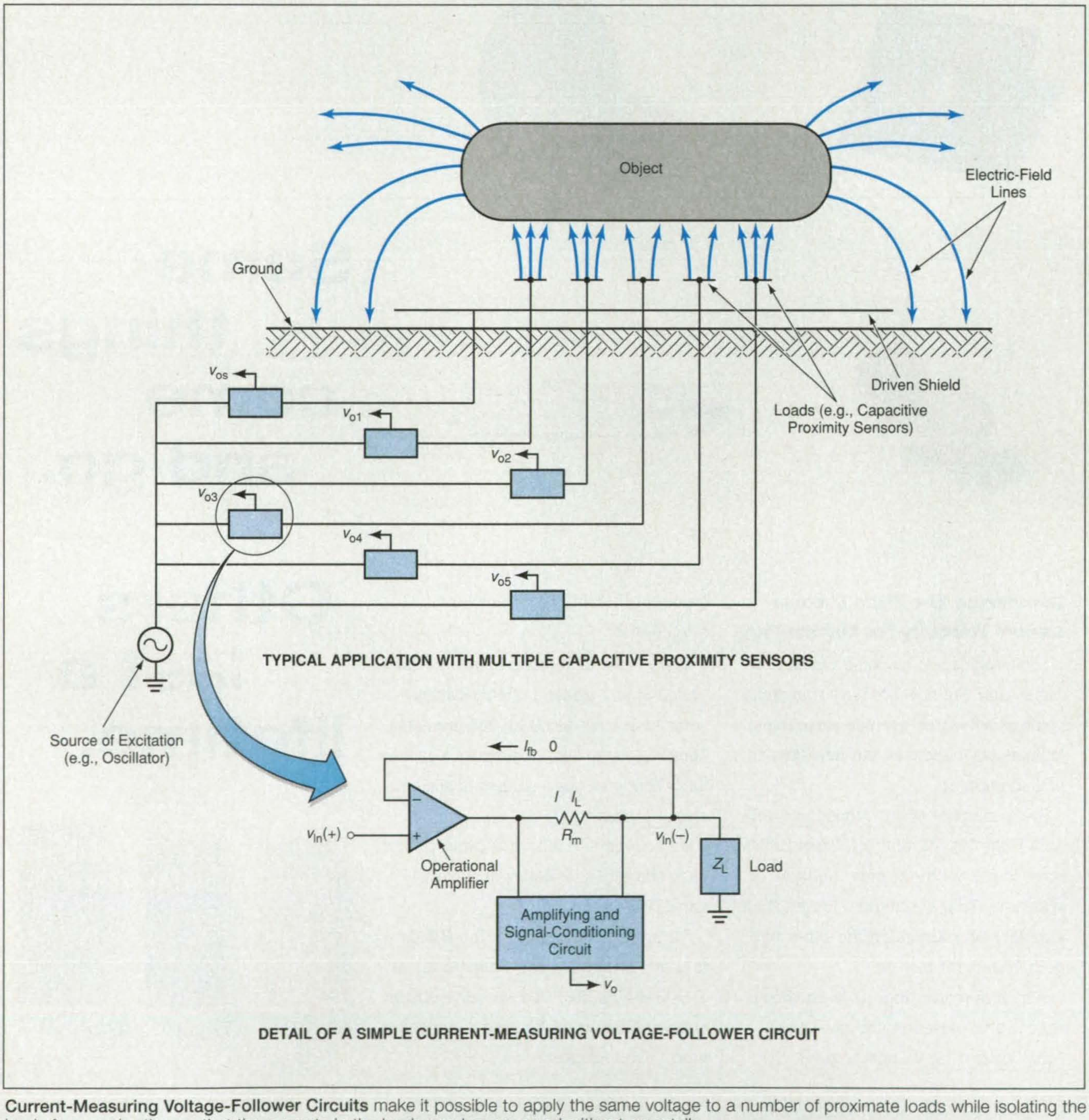
Currents in sensors driven at the same voltage can be measured without crosstalk.

*Goddard Space Flight Center, Greenbelt, Maryland*

Current-measuring voltage-follower circuits have been devised for measuring currents in proximate loads driven at the same input voltage, without incurring crosstalk by virtue of the proximity of the loads. In the original application, the loads are capacitive proximity sensors connected in parallel to a crystal-controlled oscillator, as shown in the upper part of the figure.

A current-measuring voltage-follower circuit is an operational-amplifier circuit that, as the name suggests, contains both a voltage-follower circuit and a current-measuring circuit. A voltage follower is used because its combination of high input impedance and low output impedance ensures that the desired input voltage (e.g., the voltage from the crystal oscillator) is applied to the load (e.g., the capacitive sensor). There is no crosstalk because all loads are driven at the same voltage amplitude, frequency, and phase.

The lower part of the figure illustrates one of many possible variations of the basic concept of a current-measuring voltage-follower circuit. The input voltage, $v_{in}(+)$, is applied to the noninverting (+) input terminal of an operational




**Current-Measuring Voltage-Follower Circuits** make it possible to apply the same voltage to a number of proximate loads while isolating the loads from each other so that the currents in the loads can be measured without crosstalk.

amplifier. The output terminal of the operational amplifier is connected to the load through resistor $R_m$, which is used to measure the load current, $i_L$. The operational amplifier is connected in a voltage-follower configuration by feeding the load voltage, $v_{in}(-)$, back to the inverting (–) input terminal.

Provided that the operational amplifier functions in the usual way, with high open-loop gain and negligible feedback current ($i_{fb} \approx 0$), the circuit will exhibit the voltage-follower property [$v_{in}(-) \approx v_{in}(+)$] and the current through $R_m$ will closely approximate $i_L$. It is then a simple matter to determine $i_L$ from the voltage drop $v_m = i_L R_m$ caused by the load current flowing in $R_m$: $v_m$ is sensed by an amplifying and signal-conditioning circuit that generates an output voltage, $v_O$, proportional to $i_L$.

*This work was done by John M. Vranish of* **Goddard Space Flight Center**. *For further information,* ***write in 50*** *on the TSP Request Card.*

*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, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13563.*

# Combined Active and Passive Cooling of High-Power Electronic Circuits

Thermoelectric devices and diamond films would provide cooling for high-power electronic circuits.

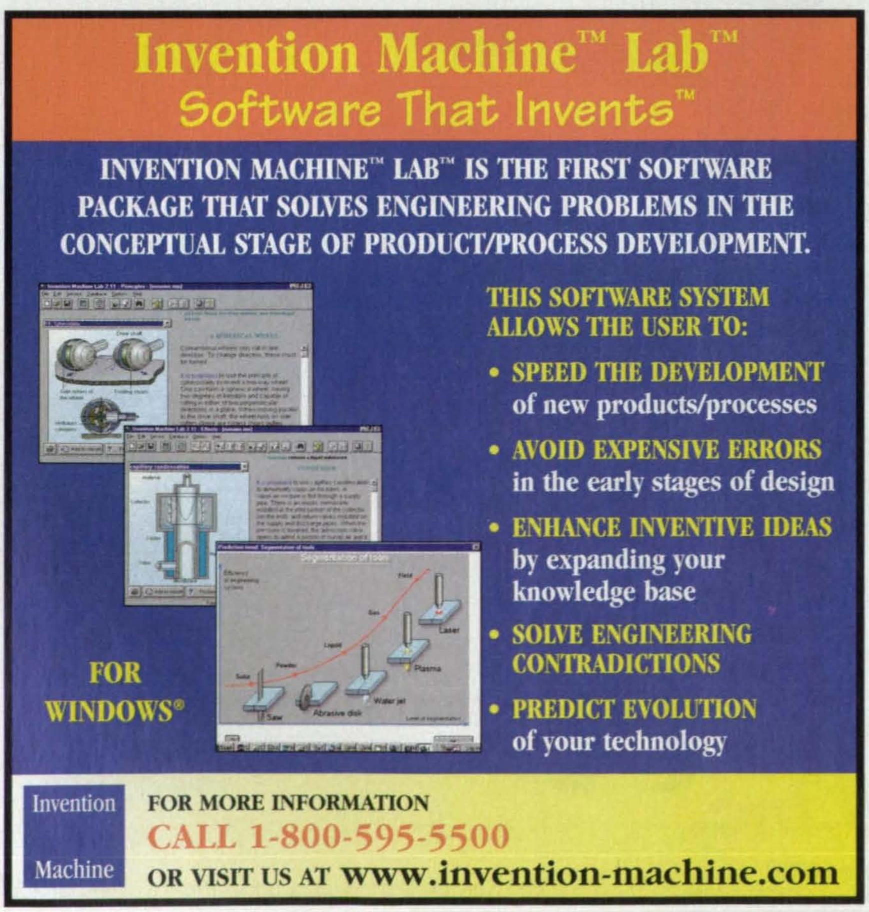
*NASA's Jet Propulsion Laboratory, Pasadena, California*

Some high-power, high-density electronic circuits would be cooled by a combination of active and passive means, according to the new technology reported here. Diamond films would be used as low-thermal-resistance heat spreaders for passive cooling and thermoelectric cooling devices would perform the active cooling.

These two techniques of passive and active cooling are well-known; the novel aspect of the proposal lies in combining them (see figure) to satisfy exceptional cooling requirements that exceed the capabilities of either technique alone. Current state-of-the-art bulk thermoelectric coolers have alumina substrates on the top and the bottom of the thermoelectric elements (cooler legs). The thermal conductivity of alumina is low (about two orders of magnitude less than that for diamond) so that heat generated by a power device placed on top of the thermoelectric cooler will not spread out. This results in a small hot spot that cannot be handled (i.e., pumped) by the cooler. Replacing the alumina with a diamond substrate will result in spreading of the heat, thus reducing the heat flux density, making it possible for the cooler to pump the heat and cool the device. Cooling high-power electronic devices by either only passive cooling or a combination of passive and active cooling results in increased reliability, lifetime, efficiency and clock speed. Specifically, using a diamond/cooler combination to cool the device to below the ambient temperature of the heat sink (circuit board), will result in increased clock speed in the case of microprocessors.

Replacing the bulk thermoelectric cooler (1- to 2-mm-thick legs) with a bulk microcooler (100- to 500-μm-thick legs) or by a thin film cooler (30- to 100-μm-thick legs) will not increase the efficiency of the cooler, but will dramatically increase the cooling-power density and allow the size of the cooler to be reduced in all three dimensions. Power devices producing 30 W (or approximately 100 W/cm$^2$) or more, can now effectively be cooled. The feasibility of thin-film thermoelectric coolers has been demonstrated, but they still need to be developed.

To optimize the design of the thermoelectric cooler and operate at maximum efficiency, diamond films would be used as thermal lenses; that is, they



would be used to spread the heat from small, high-power devices to the larger thermoelectric cooling devices. The actual power-chip to diamond-substrate cross-section ratio will depend on the heat flux density to be dissipated and on the cooling power capacity of the thermoelectric microcooler.

Besides cooling a device to below ambient to increase efficiency and clock speed, there are two other situations in which active cooling would be useful: (1) a device or electronic component dissipates high power for very short times (i.e., the cooler effectively manages temperature spikes), and (2) a component must operate at a temperature much lower than that of other components in the same circuit.

In those instances in which circuit components operate above ambient temperature, diamond films alone would be sufficient to cool these devices by effectively conducting the heat throughout the circuit board. Diamond is well-suited for passive cooling because it is an electrical insulator and has a room temperature conductivity of about 2,400 $Wm^{-1}K^{-1}$. Because this is the highest known room-temperature thermal conductivity of any material, diamond films can be expected to set the limits of passive-cooling capability. At present, diamond films still cost too much for general use, and all the problems of metallization, bonding and contact have not been solved yet. Nevertheless, diamond films offer a tremendous improvement in passive control of the temperatures of electronic circuits over that achievable with other passive-cooling materials in current use.

Other high-thermal-conductivity materials (such as AlN) can also be considered for the top and bottom substrates of the thermoelectric cooler.

*This work was done by Jan W. Vandersande, Richard Ewell, Jean-Pierre Fleurial, and Hylan B. Lyon of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 2*** *on the TSP Request Card.*

*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*

*Larry Gilbert, Director*
*Technology Transfer*
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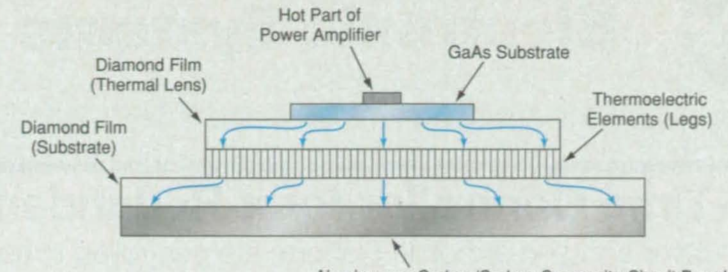
*Refer to NPO-19515, volume and number of this* NASA Tech Briefs *issue, and the page number.*




A **Power Amplifier** would be mounted on a larger diamond film (thermal lens), which would spread out the heat from the amplifier. This heat would be pumped by the thermoelectric legs and would then be conducted away by the bottom diamond substrate.





**For More Information Write In No. 407**

# Real-Time Controller for a Redundant Robot

A manipulator arm and a mobile platform are controlled in coordinated fashion.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A control system based on the configuration-control formalism has been devised for an eight-degree-of-freedom robot that includes (a) a platform that moves along a track (one degree of freedom) and (b) a seven-degree-of-freedom manipulator arm mounted on the platform. Of the eight degrees of freedom, two are redundant. The basic concept of applying the configuration-control formalism to a robot that has redundant degrees of freedom and that includes a manipula tor arm on a mobile platform was discussed in "Coordinated Control of Mobile Robotic Manipulators" (NPO-19109), *NASA Tech Briefs,* Vol. 19, No. 10 (October, 1995), page 1b.

The manipulator arm includes seven revolute joints in an alternating roll/pitch sequence, beginning with the base on the platform and ending with the end effector (hand). The control system coordinates the position and orientation of the hand along with the posture of the rest of the manipulator arm and the position of the platform so that the manipulator can reach around obstacles in performing its tasks (see figure).

The control system receives sensory information from two charge-coupled-device video cameras, two infrared triangulation proximity sensors, a gas sensor, a temperature sensor, and a force-and-torque sensor; all of these sensors are integrated into the end effector. An operator interacts with the control system and robot via two control joysticks and an IRIS computer workstation. The control system includes a real-time microprocessor that comprises two MC68040 processor circuit boards and that executes advanced control algorithms, plus a shared memory interface that enables rapid communication with other systems. The key algorithms, all written in C language and implemented in a VersaModule Eurocard (VME) environment, perform the following computations:

- Forward kinetics and the corresponding Jacobian;
- inverse kinematics with robustness in the presence of singularities;
- real-time generation of trajectories; and
- compensation of and for readings of proximity sensors.

*This work was done by Homayoun Seraji, David Lim, and Thomas Lee of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 59*** *on the TSP Request Card.*

*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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*Technology Commercialization*
*JPL-301-350*
*4800 Oak Grove Drive*
*Pasadena, CA 91109*

*Refer to NPO-19511, volume and number of this* NASA Tech Briefs *issue, and the page number.*

The **Robotic Manipulator** performs simulated inspection of a structure in a laboratory demonstration. The manipulator reaches around obstacles, which can include parts of the structure undergoing inspection.

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**For More Information Write In No. 635**

# Adaptive MIMO Neural-Network Controller for Vibration Suppression

Multiple-input, multiple-output adaptive controller based on a neural network will be trained during operation.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

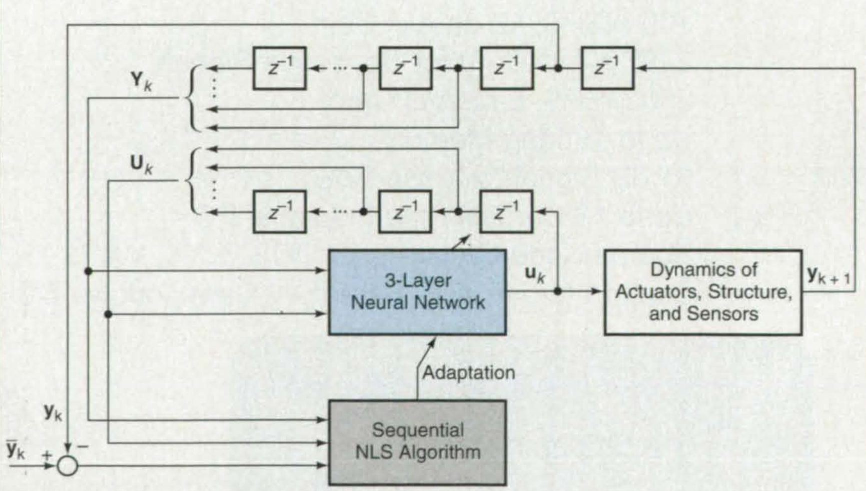
A neural-network-based adaptive control system is proposed for suppression of vibrations in flexible structures. This controller consists of a three-layer neural network and is an extension and improvement of the one described in "Neural-Network Controller for Vibration Suppression" (NPO-19138), *NASA Tech Briefs,* Vol. 19, No. 11 (November, 1995), page 94, to allow for applications to multiple-input and multiple-output (MIMO) systems.

The development of the system is based on output feedback (feedback of the measurements of the system outputs) rather than state feedback (feedback representative of the dynamical state of the structure). The use of output feedback is advantageous, particularly in flexible structure applications, where the system states are not readily available for measurement. The output feedback consists of measurements obtained from various sensors distributed on the structure.

The operation of this control system will not depend on knowledge of a mathematical model of dynamics of the structure. Instead, the system would tune itself — that is, it would adapt itself to respond in the presence of the initially poorly known and possibly changing dynamics — during operation. The adaptation would involve training the neural network (see figure) to make the outputs converge toward the desired values, as described below.

The three-layer feedforward neural network includes an input and an output layer of neurons with linear activation functions plus a hidden layer of neurons with sigmoid activation functions. In principle, the neural network could be trained by a simple gradient-descent technique, in which the weights (strengths) of the synaptic connections among neurons would be adjusted in proportion to the gradient, in synaptic-connection-weight space, of a quadratic error measure or penalty function proportional to the sum of squares of differences between the actual and the desired outputs.

Unfortunately, convergence in a simple gradient descent can be unacceptably slow for real-time adaptation in practical situations. Accordingly, this neural network will be tuned by the sequential nonlinear least-squares (NLS) algorithm, which follows a prediction-error approach and is computationally more complex but can yield faster con-




The **Neural Network Is Trained in Real Time** to suppress vibrations. The training will be effected by the sequential NLS algorithm, which will adjust the synaptic weights at each time step, $k$, to make the actual outputs (represented by sensor readings $\mathbf{Y}_k$) converge toward the desired (zero-vibration) values $\bar{\mathrm{Y}}_k$. The $z$-transform rectangular boxes represent unit-time-step delays.

vergence. This approach has been tested by computer simulation for a mathematical model of a six-input and six-output control system with an antennalike, spider-web-shaped flexible structure. The simulations demonstrated rapid adaptation and high performance in suppression of vibrations. However, some caution may be advisable: the stability of systems based on this approach remains in question because thus far, there has been no proof of convergence of the NLS algorithm for nonconvex problems.

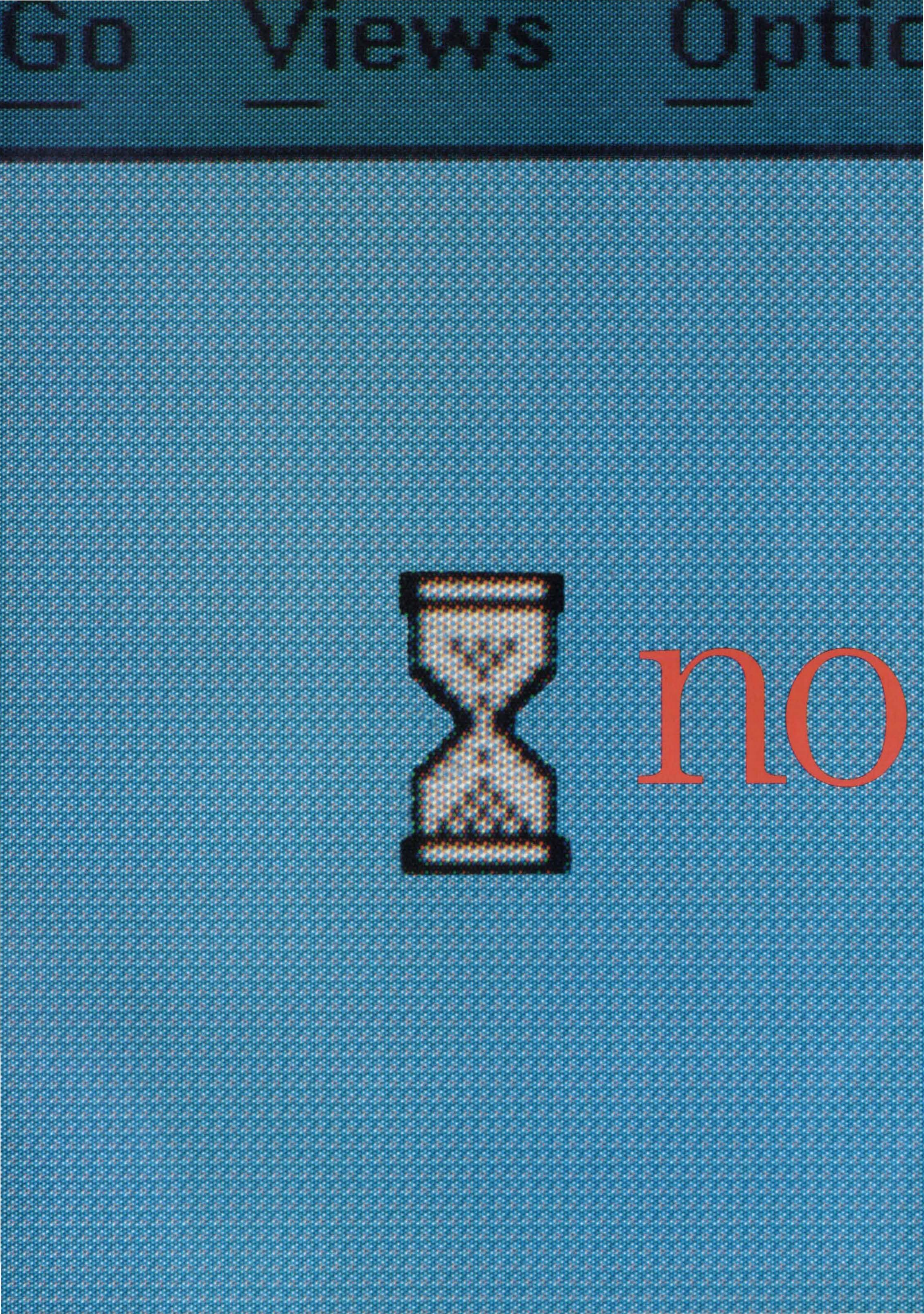
*This work was done by Dhemetrios Boussalis and Shyh Jong Wang of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 15*** *on the TSP Request Card. NPO-19299*

## Real-Time Signal-Stability Analyzer

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A system of analog and digital electronic circuits has been developed for use in analyzing the frequency-stability characteristics of radio signals and frequency standards. Designed for testing equipment to be used in spacecraft radio-science experiments, the system may also be adaptable to terrestrial use in standards laboratories, communication systems, and laboratories concerned with analysis of audio signals. Unlike prior stability analyzers, this system performs analyses in real time, measuring and computing such characteristics as power, phase, and amplitude spectra; Allan deviation; and time series of amplitude, phase shift, and differential phase shift. Noise floors for Allan deviation of 100-MHz frequency standards are $6 \times 10^{-15}$ at 1 second and $3 \times 10^{-17}$ at 1000 seconds. Noise floors for single-sideband phase spectrum (> 100 Hz from the carrier) are −142 dBc/Hz for 100-MHz frequency standards and −105 dBc/Hz for baseband analog signals. The system employs analog preprocessing and vectorized digital signal processing. A radio-frequency and analog assembly conditions and converts input analog signals into a form usable by a controller unit, either by direct analog-to-digital conversion or by a zero-crossing technique. This redundancy allows cross-checking of phase-shift tests. The controller unit, through its dedicated software, provides an operator interface. Test procedures and digital signal processing are specified and executed via an execution script in C and Fortran software. The software provides for selection of the type of test, controls details of switches and instrumentation, acquires data from analog-to-digital converters and a time interval counter, analyzes the acquired data, and structures the presentation of results.

*This work was done by Julian C. Breidenthal, Paul F. Kuhnle, Gerard Benenyan, Charles A. Greenhall, Robert L. Hamell, Emil R. Kursinski, Eric A. Theis, and John P. Vitek of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 16*** *on the TSP Request Card. NPO-19810*

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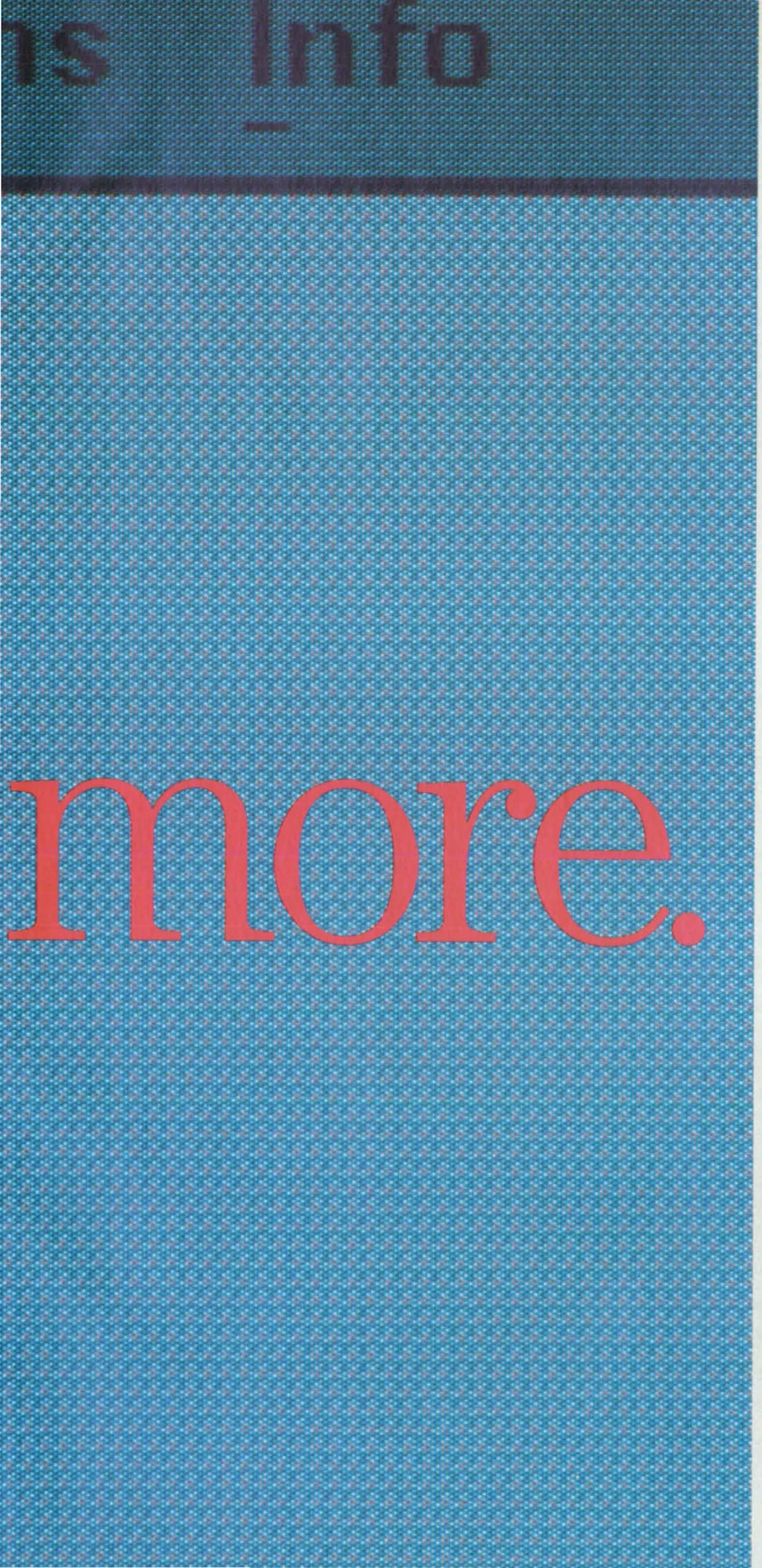


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## Measuring Effective Emittances of Insulating Blankets

A straightforward procedure gives definitive data.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A test method provides data on the effective emittances of multilayer insulation (MLI) blankets in a vacuum. The method is based on an equation for an effective emittance, $\varepsilon_{eff}$, derived from the Stefan-Boltzmann radiation law:

$$\varepsilon_{eff} = Q / A\sigma\left(T_H^4 - T_C^4\right)$$

where $\sigma$ is the Stefan-Boltzmann constant and $Q$ is the net thermal power radiated through a surface of area $A$ from the hot side at temperature $T_H$ to the cold side at temperature $T_C$.

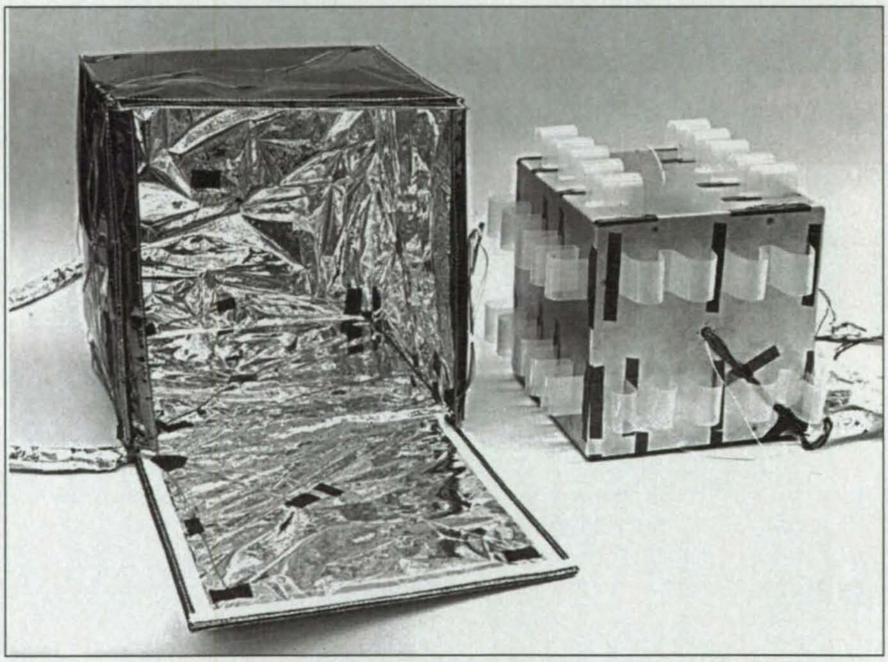
The method accommodates options for measurements in various hardware configurations that require different interpretations of the equation with respect to the values of $A$, $T_H$, and $T_C$ that most nearly represent the behavior of the equipment on which MLI blankets of the type under test will eventually be installed. The test configuration can thus be chosen so that the value of $\varepsilon_{eff}$ computed from the test data is appropriate to the size and shape of the equipment in the intended application and that it incorporates the effects of such discontinuities as seams and holes in the MLI blankets.

In this method, an MLI blanket is wrapped around an instrumented aluminum box shaped like the equipment in the intended application and the blanket-covered box is suspended within (but not touching) a liquid-nitrogen-cooled shroud in a vacuum chamber. The box is heated from its interior with a controlled amount of power, and temperatures are measured by thermocouples at various points inside the box, on the inner and outer layers of the blanket, and on the shroud. Thus, heat from the box is conducted and radiated through the blanket, then radiated from the blanket to the shroud (see figure). Once a steady state is reached, the temperatures and heater power are recorded for use in computing $\varepsilon_{eff}$.

The test method is easily applicable to three distinct MLI-hardware configurations typically encountered: the blanket is snugly wrapped on the hardware, separated from the hardware by standoffs (see figure), or loosely draped over the hardware like a tent. The tests in the various configurations produce reliable results, so that values of $\varepsilon_{eff}$ and the effectiveness of MLI in various configurations can readily be compared. The effects of discontinuities can be determined by comparing the $\varepsilon_{eff}$ values and geometric parameters of blankets that contain discontinuities with those of continuous blankets.

*This work was done by Edward I. Lin of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 36*** *on the TSP Request Card.*

*NPO-19641*



A **Blanket Is Wrapped** around an instrumented aluminum box, separated from the box by Mylar (polyethylene terephthalate) standoffs. The assembly will be hung by a stainless-steel wire in a cooled shroud in a vacuum chamber for testing.

## Powered Threaded Coupling Mechanism

A bolt and nut are automatically aligned to resist cross threading.

*Marshall Space Flight Center, Alabama*

A powered bolt-and-nut coupling mechanism is designed to accommodate initial misalignments and to correct for them, without incurring cross threading. The mechanism is intended for use in a robotic or otherwise remotely controlled assembly of a structure, or in other situations in which it would be inconvenient, difficult, or impossible for a human technician to intervene to align a nut and bolt and tighten them properly.

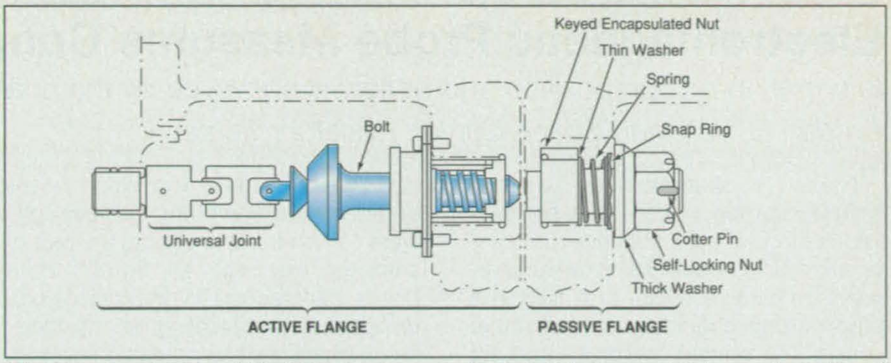
The mechanism (see figure) includes a bolt assembly and a nut assembly. The bolt assembly is mounted on a substructure called the "active flange"; this substructure is part of one of the two structures that are to be joined. The nut assembly is mounted on a substructure called the "passive flange," which is part of the other of the two structures to be joined.

The active flange contains a motor that drives the bolt assembly through a universal joint that mates with the bolt through a sliding hexagonal shaft. A threaded follower engages the thread on the bolt. The follower can slide axially along a guide, which restrains the follower against rotation. The follower causes the bolt to translate axially when the bolt is not engaged with the nut assembly.

When the bolt first makes contact with a keyed encapsulated nut in the nut assembly, the conical surface at the tip of the bolt interacts with a cup-like surface on the keyed encapsulated nut; this interaction forces the axis of the nut into approximate alignment with that of the bolt. As the bolt continues to advance, a short, unthreaded section of the bolt makes contact with the nut thread, pushing the nut back slightly against a spring preload. This action reduces the misalignment further. As the bolt advances farther, its thread engages that of the nut. The bolt then pulls on the nut and the follower translates back toward the bolt head.

If the bolt and nut are initially grossly misaligned, the contact with the bolt simply forces the nut to retreat, compressing the spring. This action prevents engagement of the threads and thus prevents the cross threading that would occur if engagement were to occur during gross misalignment. Similarly, when debris are present, the nut is forced away, preventing engagement.

*This work was done by Kem B. Robertson, Harry K. Warden, Erik A. Illi, Richard D. Turner, Alan H. Dillon, Carey L. Luce, Marty W. Jalovec, Greg T. Clark, Dean C. Sorensen, Steve R. Thompson, and Jeff W. Coops of Boeing Defense and Space Group for* **Marshall Space Flight Center.** *For further information,* ***write in 24*** *on the TSP Request Card.*
*MFS-28927*




The **Cone on the Tip of the Bolt** effects approximate initial alignment between the bolt and the keyed encapsulated nut. Further rotation and advance of the bolt results in engagement of the bolt and nut threads. As the bolt tightens in the nut, the follower slides back (leftward in this view).

# Electromagnetic Probe Measures Conditions in Fluid

Information on composition and/or flow is conveyed by the phase of a reflected signal.

*Lyndon B. Johnson Space Center, Houston, Texas*

Figure 1 illustrates an electromagnetic-probe system that provides information on the instantaneous composition, flow conditions, or other time-varying characteristic(s) of a fluid in a pipe, mixing chamber, tank, or other vessel. The system could be used, for example, in such diverse applications as measuring the relative quantities of liquid and vapor flowing in a pipeline, detecting gas bubbles in a cryogenic liquid in a tube, measuring the level of liquid in a tank, and measuring the buildup of lard in a flow of sewage.

Basically, the probe consists of the small capacitance at the end of a coaxial cable, which extends through the wall of the vessel, terminating abruptly at a location approximately flush with the inner surface. (Alternatively, the inner conductor of the cable can be made to intrude somewhat into the vessel to sample in a volume that extends farther from the wall.) The probe is excited by a radio-frequency signal (at a frequency of 700 MHz in a prototype of the system). The system includes a phase detector, which measures the phase shift of the signal reflected from the probe back toward the source. This phase shift depends on the dielectric properties of the liquid and/or gas in the vicinity of the probe tip. The dielectric properties, in turn, depend on composition and on flow conditions — principally, pressure and temperature. Optionally, one could build a system with multiple probes (see Figure 2) to measure flow conditions simultaneously at different locations or to determine the level of a liquid.

The output of the phase detector is digitized on a data-acquisition board and sent to a computer. Custom software can be used to control the rate of sampling (as high as 25,000 data points per second in the prototype), disposition, and scaling of the measured phase shift as a function of time. The data from each measurement are recorded for immediate or subsequent analysis and display in graphical form.

*This work was done by G. D. Arndt and T. Nguyen of* **Johnson Space Center** *and J. R. Carl of Lockheed Engineering & Sciences Co. For further information,* ***write in 3*** *on the TSP Request Card.*

*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; (713) 483-4871. Refer to MSC-22366.*

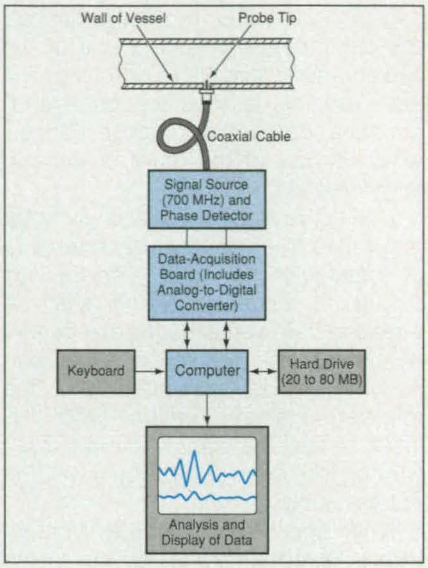



Figure 1. The **Phase Shift of the Signal Reflected From the Probe Tip** is indicative of the dielectric properties (and thus of the composition and/or flow conditions) of the fluid in the vicinity of the probe tip.

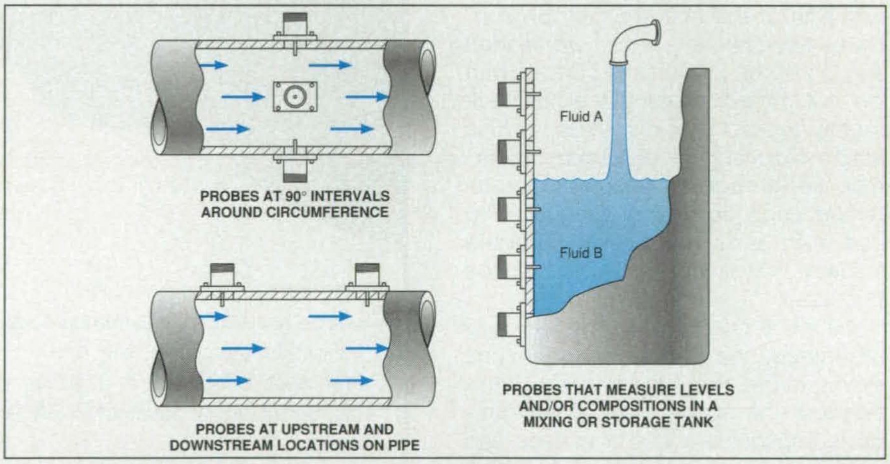



Figure 2. **Multiple Probes** can be used to sample conditions simultaneously or sequentially at different locations.

# Statistical Filtering for Resolution of GPS Phase Ambiguities

Less computation is needed than in integer-search methods.

*Marshall Space Flight Center, Alabama*

An improved method for resolution of integer-cycle-count ambiguities in the measured phases of carrier signals received at terrestrial stations from Global Position System (GPS) satellites requires less computation than do integer least-squares regression methods developed for the same purpose. The method involves (1) the use of a pair of GPS receiving stations separated by a baseline of length $B$, (2) statistical filtering of differences between the GPS-carrier-phase measurements taken at the two stations, and (3) some consideration of the angle ($\phi$) between the baseline and the line of sight to each GPS satellite observed (see figure).

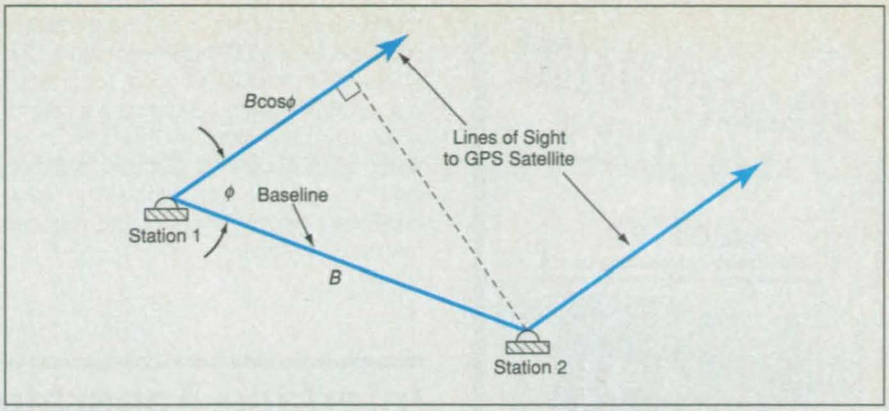
Each integer cycle of phase ambiguity is associated with a one-wavelength ambiguity in position. Therefore, resolution of the phase ambiguities is necessary for determining the locations of the phase centers of the receiving antennas precisely; that is, to within the irreducible minimum errors (typically between 2 and 20 mm) imposed by noise in the carrier-phase-tracking loops of the receivers. To state it more precisely, once the phase ambiguity at a given receiving station has been resolved, the phase-equivalent range (phase-equivalent distance to the GPS satellite) is known within the precision allowed by phase noise.

In the improved method, successive estimates of phase ambiguities (and of differences between them) at a pair of stations are monitored to determine when estimation errors have passed below designed thresholds of convergence. When this occurs, the estimated phase ambiguities are constrained to integer cycle counts to reflect the true nature of phase ambiguity, and the associated covariances are constrained accordingly.

Consider stations 1 and 2 tracking a given satellite with phase measurements of $Z_1$ and $Z_2$ and associated ambiguities of $K_1$ and $K_2$ cycles, respectively. Let $N = K_1 - K_2$. The estimation process reveals an approximate continuous value of $N$ as successive measurements are incorporated. The decision whether or not to constrain the ambiguities to integer values is made by testing for the convergence of $|N|$ and its associated covariance to designed values within designed threshold error levels. The process is implemented with an algorithm based on a covariance analysis of three independent random variables and their respective unbiased estimates.

The improved method is further based on the observation that when phase ambiguities are eliminated and in the absence of phase measurement errors and noise, the phase measurements are related to the baseline, to the line of sight to the satellite, and to the wavelength ($\lambda$) of the GPS signal by the equation $(Z_1 - Z_2)\lambda = B\cos\phi$. By taking the differences between (1) $Z_1 - Z_2$ and $B\cos\phi$. for the given satellite and (2) $Z_1 - Z_2$ and $B\cos\phi$. for another satellite (such a difference is called a "second difference"), one can eliminate those measurement errors that are attributable to signal-propagation delays in cables and radio-frequency circuits.

When phase ambiguities are observable, they can be estimated by statistical filtering of carrier-phase differences according to the approach outlined above. In this instance, statistical observability requires sufficiently large changes in $\phi$ between successive measurements. It has been found theoretically that the size of the change needed to observe the phase ambiguity and subsequently resolve it is given by $\Delta\phi = \arcsin(2\sigma_m/\pi)$, where $\sigma_m$ is the phase-measurement noise. For example, a phase-measurement noise of about 0.1 radians gives $\Delta\phi = 0.0637$ radians. The angular rate of change of the line of sight to an attitude-




The **Angle φ and Its Rate of Change** with orbital motion of the satellite affect the statistical observability of phase ambiguities.

stabilized spacecraft in low Earth orbit is only about 0.00023 radians/second. The observation interval needed to achieve $\Delta\phi$= 0.0637 radians, and thus successful ambiguity resolution, at that rate is as much as 277 seconds. Simulation experiments and real-data processing have confirmed that estimate of the required resolution interval.

*This work was done by Haywood Satz for* **Marshall Space Flight Center**. *For further information,* ***write in 95*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26390.*

## Interface Apparatus for Gas Chromatography

### Selective loss of less volatile and more polar compounds in gas samples is minimized.

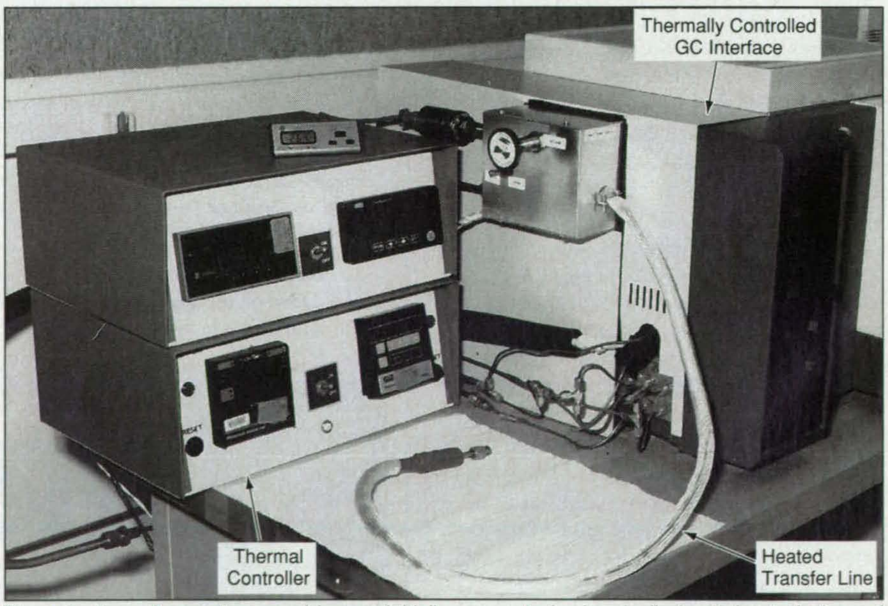
*Lyndon B. Johnson Space Center, Houston, Texas*

The figure shows a thermally controlled interface apparatus that is used to transfer a sample of gas from a sample container to a gas chromatograph (GC). The apparatus is designed to minimize loss of constituents of the sample gas by leakage, condensation, and/or chemical reaction. The apparatus includes a heated, evacuable, chemically inert transfer tube that connects the container to the gas chromatograph.

When a container is connected to the apparatus, a technician opens a valve to a vacuum pump, which evacuates residual gas from the interior of the apparatus. After evacuation, the technician closes the valve to the vacuum pump and opens the valve between the container and the apparatus, admitting the gas sample to the interior of the apparatus. The gas sample then travels through the interior of the apparatus to the input port of the GC, without alteration of its composition.

All parts of the apparatus that come into contact with the gas sample – including the valves and the transfer tube – are made of stainless steel lined with fused silica to ensure that the gas encounters only chemically inert surfaces. The transfer tube and other critical components are wrapped with electrical-resistance heating tape, which is used to maintain a controlled temperature to prevent condensation of less volatile components of the gas sample.

*This work was done by Michael G. Bell, Kristin Gillis, Gary Moffett, and Timothy Shelly of Lockheed Engineering and Sciences Co. for* **Johnson Space Center.** *No further documentation is available.*
*MSC-22478*




The **Interface Apparatus** provides an initially evacuated, chemically inert, heated channel through which a gas sample can flow from a container to a gas chromatograph. Low-volatility and polar constituents of the gas arrive for analysis along with highly volatile components.

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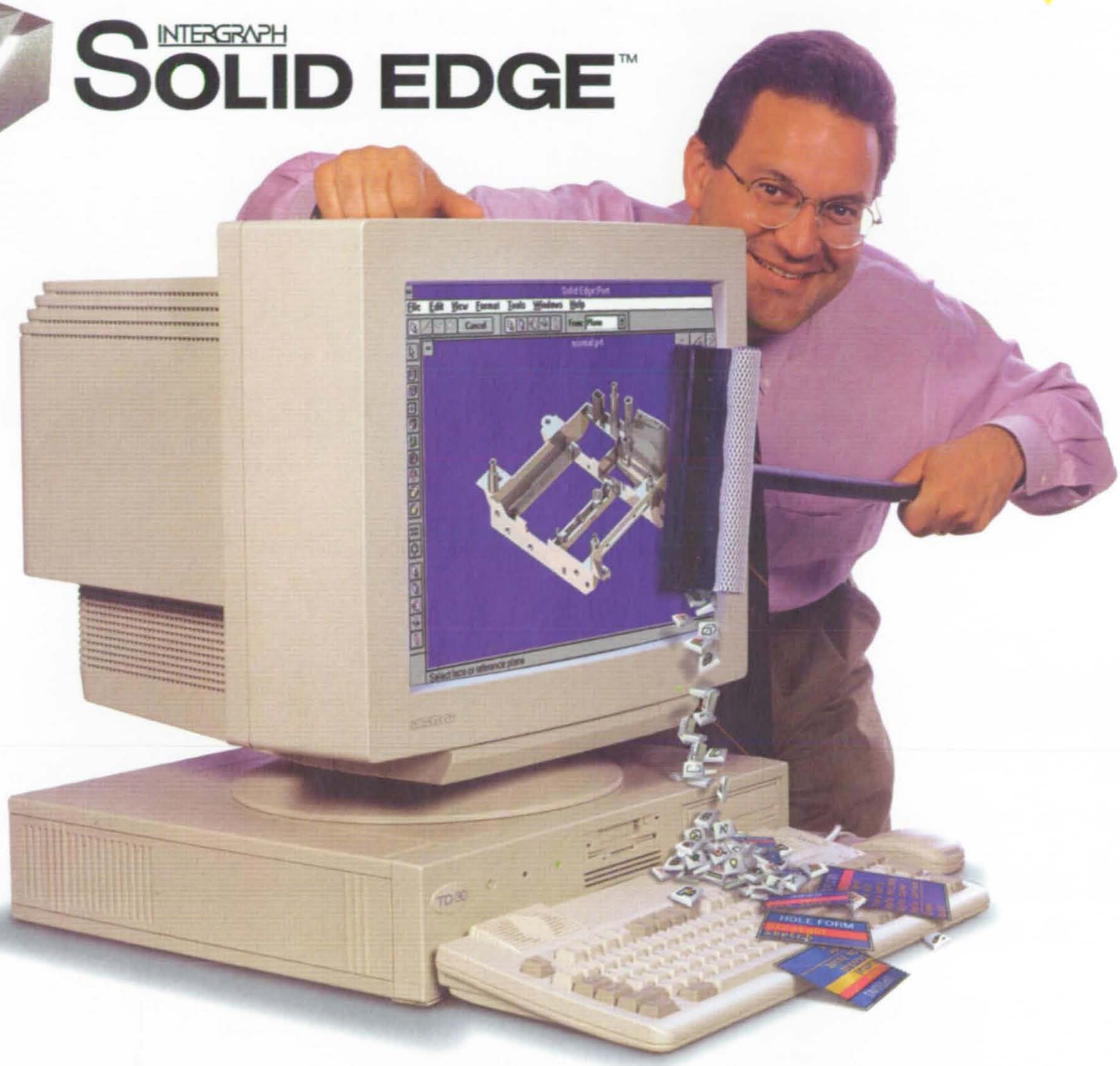

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# Quartz-Crystal Microbalances Coated With Zeolites

The zeolite coats would increase sensitivity for measuring contaminants.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Quartz-crystal microbalances (QCMs) used to measure concentrations of contaminants in the air, in vacuums, and in special scientific and industrial atmospheres would be coated with a zeolite, according to a proposal. The zeolite would greatly increase the quantities of volatile contaminants adsorbed, thereby greatly increasing the sensitivity of the QCMs as contamination monitors.

The particular zeolite formulation and the technique for applying it to surfaces was described in "Highly Efficient Molecular Adsorbers" (NPO-19345) *NASA Tech Briefs*, Vol. 20, No. 5 (May, 1966), page 60. An aluminum electrode on the sensing crystal of a commercial QCM would be coated with the zeolite to the required thickness, which would necessarily be a compromise: the thickness should be great enough to provide adequate range for collection of contaminants, but not so great that the mass of the coat saturates the response of the QCM. For example, on a typical QCM with a useful saturation mass of 3 $\mu g/cm^2$ a zeolite coat 40 nm thick would be able to collect 0.2 $\mu g/cm^2$.

The enhanced ability of a zeolite-coated QCM to collect volatile materials at room temperature would eliminate the need for a temperature-controlled (cooled) QCM. This would be an advantage for monitoring air and other gases that contain water vapor because condensation of water on a cooled QCM gives rise to a contamination reading, which can mask the reading of another contaminant that one seeks to measure. Another advantage is that the zeolite coat could retain the sample of volatile material(s) for later analysis.

Beyond the increase in adsorbance, the other unique adsorption and desorption characteristics of the zeolite coats could also enable the use of QCMs in ways that are otherwise not possible. For example, a zeolite-coated QCM could be operated in conjunction with a heater for use as an *in situ* thermogravimetric-analysis (TGA) device. In this use, heating would result in slow, controllable desorption that could be measured by the response of the QCM. The desorption features (e.g., peaks in the rate of desorption) should be more easily separable than they are in the case of a coated temperature-controlled QCM, from which desorption is typically too fast to permit accurate characterization of its thermal-response transient.

*This work was done by Jack Barengoltz of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 58*** *on the TSP Request Card.*
*NPO-19496*

# Moving-Temperature-Gradient Heat Pipe: Alternative Concept

*John F. Kennedy Space Center, Florida*

In a proposed directional-solidification furnace for growing crystals, an ampoule containing the material to be grown would be mounted in a fixed position in the central hollow of an annular heat pipe in which the thermal gradient would be maintained by use of a liquid that would be fed into the pipe at the condenser end during operation. The thermal gradient would form at the boundary between the working-fluid vapor and the liquid feed. The temperature gradient would be made to translate along the heat pipe by feeding in additional liquid at a controlled rate. This proposal offers an alternative to the concept of using a noncondensible gas that collects in the condenser and of feeding in more of this gas to translate the thermal gradient along the pipe, as described in "Moving-Temperature-Gradient Heat Pipe for Growing Crystals" (MFS-26361), *NASA Tech Briefs*, Vol. 20, No. 8 (August, 1966), page 83. Because no moving mechanical parts would be needed for translating the temperature gradient along the ampoule, both the present concept and the concept described in the cited article offer the advantages of simplicity, ruggedness, and very little vibration (vibration is undesirable because it can disturb the crystal-growth process).

*This work was done by Donald Gillies and Sandor L. Lehoczky of* **Marshall Space Flight Center** *and Gregg J. Baldassarre and Nelson J. Gernert of Thermacore, Inc. For further information,* ***write in 19*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26362.*

# Program Simulates Particle-Fallout Witness-Plate Data

*John F. Kennedy Space Center, Florida*

A C-language computer program simulates particle-fallout data (numbers of particles in various size ranges) like those that one would gather by use of witness plates to classify a clean room or similar facility. The program was developed to investigate the statistics of witness-plate sampling, with a view toward determining the minimum witness-plate area and minimum sampling time necessary to estimate the cleanliness class of a facility with a given degree of confidence. The program models a facility with a particle-size distribution and cleanliness class defined by the user. All evaluations of the cleanliness class of a simulated facility are performed according to MIL-STD-1246, but the user can define a fallout environment (more specifically, a particle-size distribution) different from that of MIL-STD-1246; this option is provided because the particle-size distributions of many facilities do not match that of MIL-STD-1246. For the chosen distribution, the program computes the readings and the cleanliness classes that one would determine from the readings taken from an ensemble of 100 witness plates in the simulated facility. The user then evaluates the statistics of the class determinations.

*This work was done by Christian J. Schwindt of I-NET and Paul A. Mogan of* **Kennedy Space Center.** *For further information,* ***write in 68*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11844.*

# Two Potentially Useful Ternary Skutterudite Compounds

These compounds may be suitable for thermoelectric devices that operate at relatively low temperatures.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

$Ru_{0.5}Pd_{0.5}Sb_3$ and $Fe_{0.5}Ni_{0.5}Sb_3$ are ternary skutterudite compounds that have recently been synthesized and found to exhibit potentially useful thermoelectric properties. This development is an intermediate product of a continuing investigation of skutterudites as materials with promising semiconducting and thermoelectric properties.

Some other results of this investigation were described in "Skutterudite Compounds for Power Semiconductor Devices" (NPO-19378) *NASA Tech Briefs*, Vol. 20, No. 3 (March 1996), page 60. That article focused on the binary skutterudites $CoSb_3$, $RhSb_3$, $IrSb_3$. A ternary skutterudite is isoelectronic to a binary skutterudite and can be conceptually derived by replacing every two transition-metal atoms in a binary skutterudite with one atom of the element immediately to the left of that transition metal and one atom of the element immediately to the right of that transition metal in the periodic table of elements. Thus, $Ru_{0.5}Pd_{0.5}Sb_3$ is derived from $RhSb_3$ by substituting ruthenium and palladium for rhodium atoms, while $Fe_{0.5}Ni_{0.5}Sb_3$ is derived from $CoSb_3$ by substituting iron and nickel for cobalt.

In experiments, single-phase, polycrystalline samples of $Ru_{0.5}Pd_{0.5}Sb_3$ and $Fe_{0.5}Ni_{0.5}Sb_3$ were synthesized by direct combination of the elements: In the case of $Ru_{0.5}Pd_{0.5}Sb_3$, powders of ruthenium (99.997 percent pure), palladium (99.9 percent pure), and antimony (99.9999 percent pure) were mixed in stoichiometric ratio in a plastic vial, then loaded and sealed in a quartz ampoule under vacuum. The ampoule was then heated for 8 days at a temperature of 600 °C. The product was removed from the ampoule, crushed in an agate mortar, reloaded in a second quartz ampoule, and heated for annealing for 4 days at 550 °C. $Fe_{0.5}Ni_{0.5}Sb_3$ was prepared similarly except that the transition-metal powders were iron (99.999 percent pure) and nickel (99.996 percent pure), and the first heating was for 4 days at 750 °C.

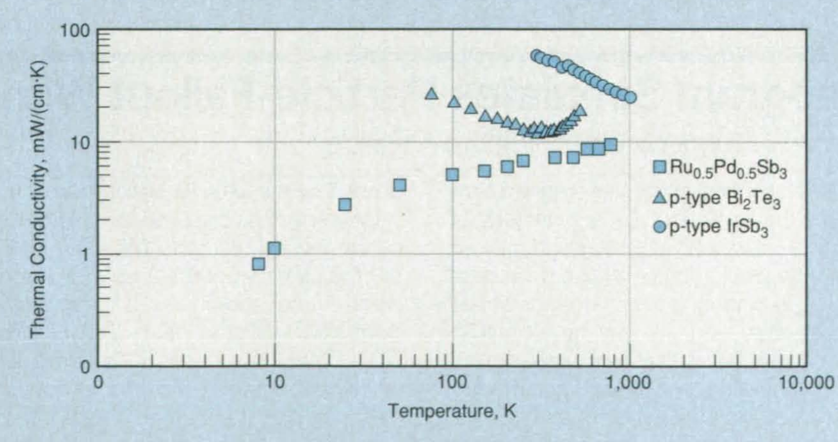
After annealing, the powders were removed from the ampoules and analyzed by X-ray diffractometry. High-density samples were made by pressing the annealed powders at a pressure of about 20 kpsi (140 MPa) at a temperature of 500 °C for 2 hours. Some of the thermoelectric properties of these skutterudite samples were measured. The X-ray spectra could be indexed on the basis of primitive unit cells with reflections corresponding to those of the skutterudite structure. The calculated lattice constants and some thermoelectric properties of the $Ru_{0.5}Pd_{0.5}Sb_3$ and $Fe_{0.5}Ni_{0.5}Sb_3$ samples are summarized in the table.

One particularly notable property of $Ru_{0.5}Pd_{0.5}Sb_3$ is its thermal conductivity;

| Material | $Ru_{0.5}Pd_{0.5}Sb_3$ | $Fe_{0.5}Ni_{0.5}Sb_3$ |
|---|---|---|
| Lattice constant, Å | 9.2944* | 9.1001*, 9.0904** |
| Density Determined From X-Ray Measurements, g/cm$^3$ | 7.75* | 7.46 |
| Density Determined From Other Measurements, g/cm$^3$ | 7.49* | 7.403* |
| Decomposition Temperature in Vacuum, °C | 647* | 729* |
| Conductivity Type | p* | p** |
| Electrical Resistivity, mΩ·cm | 1.45* | 1.008* |
| Hall Mobility, cm$^2$·V$^{-1}$·s$^{-1}$ | 35* | 14* |
| Hall Carrier Concentration, cm$^{-3}$ | 1.2 ¥ 10$^{20}$* | 4.5 ¥ 10$^{20}$* |
| Seebeck Coefficient, mV·K$^{-1}$ | 18* | –40* |

* Found in this Investigation  ** Reported in the Literature

These **Properties of $Ru_{0.5}Pd_{0.5}Sb_3$ and $Fe_{0.5}Ni_{0.5}Sb_3$** were measured at room temperature.




The **Thermal Conductivity** of a sample of $Ru_{0.5}Pd_{0.5}Sb_3$ at low temperature was found to be much smaller than the thermal conductivity of either a sample of $IrSb_3$ or a sample of $Bi_2Te_3$ (a state-of-the art low-temperature thermoelectric material).

the measured thermal conductivity of a sample of this material was found to be very low (characteristic of a glass) at low temperature (see figure). Most known materials that exhibit similarly low thermal conductivities also exhibit rather high electrical resistivities, but this material is an exception; its electrical resistivity is relatively low. The combination of low thermal conductivity with potentially useful electrical properties makes the phase $Ru_{0.5}Pd_{0.5}Sb_3$ an excellent candidate for thermoelectric applications. Because of its relatively low decomposition temperature (647 °C) and an estimated bandgap of 0.6 eV, this material would most likely be useful for thermoelectric-cooling applications.

*This work was done by Thierry Caillat, Jean-Pierre Fleurial, and Alexander Borshchevsky of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 28*** *on the TSP Request Card.*

*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:*

*William T. Callaghan, Manager*
*Technology Commercialization*
*JPL-301-350*
*4800 Oak Grove Drive*
*Pasadena, CA 91109*

*Refer to NPO-19409, volume and number of this* NASA Tech Briefs *issue, and the page number.*

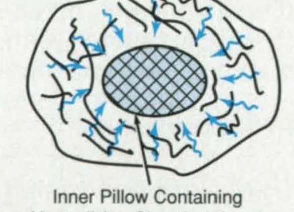
# Pads To Absorb Spilled Chemicals

These pads can contain reagents to neutralize the spilled chemicals.

*Lyndon B. Johnson Space Center, Houston, Texas*

Layered, pillowlike absorbent pads are being developed for use in containing, neutralizing, and cleaning up spilled chemicals: Each pad includes three layers (see figure): (1) an outer layer of woven polypropylene or other chemically resistant cloth; (2) a middle layer of finely divided polyethylene, silica gel, clay, sand, or other chemically inert absorbent material; and (3) an inner pillow of chemically resistant or nonresistant material that consists of an absorbent and a chemical agent that reacts with the spilled chemical. The chemical agent is selected to neutralize the specific toxic, acidic, or caustic spilled chemical; for example, a basic agent like baking soda could be used to neutralize spilled acid. The absorbent and the chemical agent could be combined physically as a mixture or combined chemically into a single material.

An experimental pad of this type consisted of a woven polypropylene outer layer, a polyethylene filler as the middle layer, and an inner pillow of nylon mesh cloth containing a filling of 10 percent copper (II) oxide supported on absorbent silica gel. The pad was fabricated by adding the inner pillow to a commercially available spill pillow. The pad was tested by using it to absorb a spill of aqueous hydrazine. The aqueous hydrazine gradually migrated to the inner pillow, where the silica gel/copper (II) oxide reagent converted the hydrazine to nitrogen and water. The tested pad was found to make for convenient disposal.




A **Spilled Chemical Diffuses** into the inner pillow, where it is neutralized by a chemical agent.

*This work was done by Dennis D. Davis of Lockheed Martin for* **Johnson Space Center.** *For further information,* ***write in 87*** *on the TSP Request Card.*

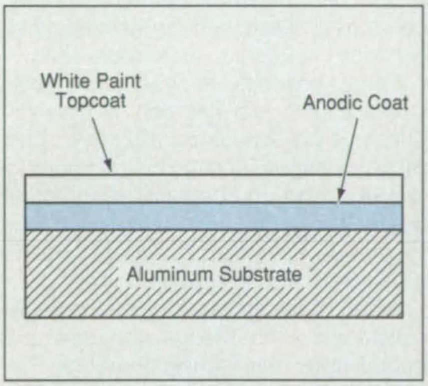
*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center; (713) 483-4871. Refer to MSC-22360.*

# Two-Layer Coat Helps Keep Aluminum Panel Cool

Thermal emissivity and absorptivity equal those of a much thicker paint.

*Lyndon B. Johnson Space Center, Houston, Texas*

A thin two-layer coating system helps keep an underlying aluminum panel cool by increasing the thermal emissivity of the aluminum surface while decreasing its solar absorptivity. The coating system withstands an oxidizing atmosphere, ultraviolet radiation, and charged particles. It adds little weight to the substrate. The coating system was developed for heat-management surfaces of a spacecraft that dissipate heat from inner structures more readily than they absorb solar radiation. The coating system could also be used on Earth to help reduce solar heating of selected parts of structures.




The **Thin Layer of White Paint** overlies the similarly thin anodically etched layer.

The two-layer coat consists of an anodized layer on the aluminum substrate and an overlayer of inorganic white paint (see figure). The anodized layer increases the emissivity of the aluminum-alloy substrate. It is produced by a new anodizing procedure in which the current density is increased in steps in a sulfuric acid bath heated above the standard temperature. The anodized layer is about 1 mil (about 25 μm) thick.

The paint is Z-93, a commercially available formulation that includes zinc oxide particles distributed in potassium silicate. The paint is applied to the anodized layer, then dried by heating in air in an oven for 24 hours. The combination of the anodized layer and a 1-mil (25-μm) thickness of the paint yields a low solar absorptivity (0.15) and high thermal emissivity (0.9) approximately equal to those of a layer of the paint 7 mils (about 180 μm) thick on an unanodized aluminum substrate.

*This work was done by Huong G. Le and Henry W. Babel of McDonnell Douglas Corp. for* **Johnson Space Center**. *For further information,* ***write in 61*** *on the TSP Request Card.*

*Title to this invention has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457(f)}, to McDonnell Douglas Corp. Inquiries concerning licenses for its commercial development should be addressed to:*

*John Scholl, Patent Counsel*
*McDonnell Douglas Corp.*
*5301 Balsa Avenue*
*Huntington Beach, CA 92647*

*Refer to MSC-21986, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# Computer Programs

## COSMIC: Transferring NASA Software

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## Electronic Components and Circuits

### Program Estimates Performances of Solar Electric Panels

The ARAYCURV computer program estimates current-vs.-voltage (IV) curves of a one- or two-panel array of solar photovoltaic cells for which only preliminary or partial design data may be available. The two panels can contain cells of different types (e.g., silicon or gallium arsenide), can be oriented at different angles with respect to the Sun, and can be at different temperatures. ARAYCURV mathematically models the array on the basis of a single-diode, lumped-parameter model of a photovoltaic cell. The user strives to fit the available data to the array model. First, the user enters data that include the number of series cells, parallel strings, sun angle, and temperature for each panel. Then the user enters data on the cells in each panel to enable computation of cell IV curves. Among the cell data are series and shunt resistances, which one may have to enter iteratively to get the resultant values of diode-model parameters and maximum-power-point IV values into reasonable agreement. The cell IV curve voltages are added to determine the IV curve for each series string, the current values from the string IV curves are added to determine the IV curves for the panels, and the IV curves for the two panels are added by interpolation to obtain the IV curve for the array. Corrections for different temperatures and insolation levels on the two panels are made use of by a fifth-order polynomial fit to calibration data. Fresnel reflectivity losses are calculated. Output data are available in tabular or graphical (IV-curve) form, as a video display, printout, or stored on magnetic disk. ARAYCURV is written in GW-BASIC for IBM PC and compatible computers.

*This program was written by Dale R. Burger of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 66*** *on the TSP Request Card.*
*NPO-19891*

## Mathematics and Information Sciences

### Advanced Scheduling and Planning Program

Request-Oriented Scheduling Engine (ROSE) is a scheduling computer program that has advanced planning and scheduling capabilities, provides a generalized graphical display, supports grouping and marking activities, uses a scheduling language, and includes an artificial-intelligence rescheduling algorithm. ROSE schedules activities specified by the user. Activities require resources, and must be scheduled subject to any number of constraints (e.g., deadlines) specified by the user. Scheduling consists primarily of allocating resources to activities and selecting a starting time for each activity. ROSE provides batch scheduling with various request-selection and placement heuristics. It also supports interactive scheduling by providing the operator with information on conflicting demands for resources, usage of resources, and graphical displays.

ROSE can generate four types of timeline plots: activity, resource, step, and possible starting times. An activity plot displays activities that use a particular resource. A resource plot shows the remaining amount of resource available for allocation. Activities consist of steps. A step plot displays a more detailed look at the schedule, and displays user-customizable annotations such as icons and text. Lastly, the possible-starting-times plot shows each resource and timing constraint that contributes to the placement of an activity on the schedule so that scheduling conflicts can be analyzed.

A grouping-and-marking capability enables the user to organize activities in different ways. A group is a collection of zero or more activities and is marked with a color designated by the user. The user can move, delete, edit, or reschedule all activities in the group as a single entity.

ROSE provides an interactive user interface. The user can control the execution of the scheduling algorithms and make changes during the scheduling process. Also, the user can drag activities along the graphical time line. Then, to provide immediate feedback, ROSE displays conflicting activities in red.

ROSE is data driven. Most of the application-unique knowledge and data are coded using the Flexible Envelope Request Notation (FERN) scheduling language. If the FERN language is used, the need to write new software is reduced or eliminated. If changes are made to the FERN data, those changes do not cause recompilation or retesting of the software. ROSE can be used in many planning and scheduling environments, including those of planning and scheduling satellite activities, managing satellite tape recorders, scheduling ground equipment, training astronauts, and training pilots.

ROSE currently schedules more than 400 activities per minute for a schedule with fewer than 2,000 activities. Performance for a schedule with as many as 20,000 activities is over 180 activities per minute. (These performance figures were obtained in benchmark tests on a VAX 3100 computer capable of handling 3 million instructions per second.)

ROSE is written in Ada for DEC VAX-series computers running VMS versions 5.4 or 5.5 and Sun4-series computers running SunOS 4.x. ROSE requires 16MB of random-access memory for execution and 32MB of disk space for installation of source, demonstration, and executable codes; however, 55MB of disk space is recommended for complete installation.

This package of software requires MIT's X Window System, Version 11 Revision 4, with OSF/Motif 1.0 or later. The DEC VAX version (GSC-13597) includes sample VAX executable codes compiled under VMS versions 5.4 and 5.5 with TAE+ v5.1, and the Sun version (GSC-13596) includes a sample Sun4 executable code compiled under SunOS with TAE+ v5.1. The standard medium for distribution of the VAX version of ROSE is a 1,600-bit/in. (≈630-bit/cm), 9-track magnetic tape in DEC VAX BACKUP format. It is also available on a TK50 tape cartridge in DEC VAX BACKUP format. The standard medium for distribution of the Sun version of ROSE is a 0.25-in. (6.35-mm) streaming-magnetic tape cartridge (Sun QIC-24) in UNIX tar format. The TAE Support Office [Greenbelt, MD; (301)286-6034] also serves as the ROSE Support Office. The development of ROSE began in 1987 and version 1.3 of ROSE was delivered to COSMIC in 1993.

*This program was written by Stuart Weinstein of Loral AeroSys for* **Goddard Space Flight Center.**

*For further information on GSC-13596,* ***write in 5*** *on the TSP Request Card.*

*For further information on GSC-13597,* ***write in 6*** *on the TSP Request Card.*

*GSC-13596/GSC-13597*

## Physical Sciences

### Program Organizes Data for the Internet

WebCat software provides index, catalog, retrieve, and display capabilities for multimedia data archives via the Internet's World Wide Web (WWW). WebCat was designed and implemented by the Data Archival and Retrieval Enhancement (DARE) project. The underlying compnent of WebCat is the use of simple "keyword= value" labels, a data-labeling standard developed by the Planetary Data System (PDS) using the Object Description Language (ODL). ODL is an object-based language that enables the specification of the classes and attributes of an entity.

WebCat organizes the keyword and value information stored in PDS labels into HyperText-Markup-Language (HTML) documents for keyword browsing. WebCat also provides a full-text and structured-field search of the label information. These HTML documents and search results lead users to particular labels and subsequently to the data identified by those labels. In effect, WebCat builds an environment for searching and presenting data that are accessible by WWW browsers such as Mosaic and Netscape. The current version of WebCat runs on UNIX workstations that support PERL and WAIS.

Whereas older methods of creating HTML documents to provide access to data required manual preparation and maintenance of source material, WebCat dynamically generates the WWW interface. Many organizations at the Jet Propulsion Laboratory take advantage of WebCat's catalog-building system including DARE itself, PDS, the Cassini Program's Electronic Library, the Electronic Labwide Information Access System (ELIAS), and the Data Distribution Laboratory. Data types include documents, diagrams, photographs, images, software, scientific data, and the like. Support for video is being added.

*This work was done by Ann M. Bernath, David P. Bernath, Rosana B. Borgen, Susan M. Hess, John S. Hughes, Jason J. Hyon, Kristy L. Kawasaki, Michael D. Martin, and Carol L. Miller of Caltech and Mark Takacs of Sterling Software for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 41*** *on the TSP Request Card.*

*NPO-19830*





**For More Information Write In No. 439**

## Heel-Strike Mechanism for Rehabilitative Knee Brace

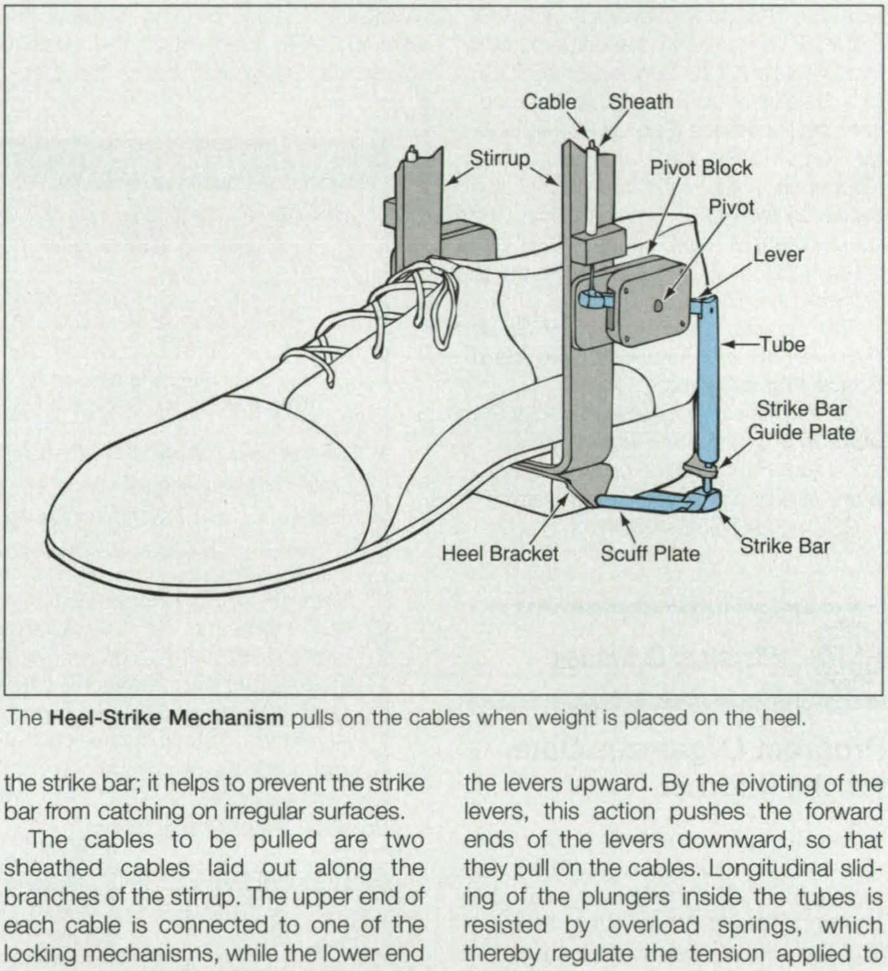
This mechanism controls a locking mechanism in the knee bar.

*Marshall Space Flight Center, Alabama*

The figure illustrates a heel-strike mechanism that is part of a knee brace for use in rehabilitating a person who has suffered some muscle damage in a leg. The knee brace was described in "Knee Brace Would Lock and Unlock Automatically" (MFS-28991), *NASA Tech Briefs*, Vol.19, No.12 (December, 1995), page 28. To recapitulate, the knee brace could lock at any bend angle, but unlike some older knee braces, this one would not prevent the knee from bearing weight. Instead, this knee brace would allow the knee to bear weight and would lock only when the foot and lower leg were bearing weight. Thus, the brace would prevent flexion that the wearer desired to prevent but could not because of weakened muscles. At other times, the knee could be bent freely to exercise the knee-related muscles.

The overall function of the heel-strike mechanism is to pull on cables attached to clutchlike locking mechanisms in the knee brace to actuate the locking function when the heel strikes the ground. The heel-strike mechanism includes a heel bracket and strike-bar guide plates that are attached to the wearer's shoe. A two-branch stirrup is fastened at its lower end to the heel bracket and at its upper end (not shown in the figure) to the main knee-brace housings at the knee.

Mounted on each branch of the stirrup is a pivot block, which supports a lever at its pivot point. The rear end of each lever is connected via a tube-and-plunger assembly to a strike bar located under the heel. The strike bar is free to move up and down within a short range. A pivoting scuff plate engages a slot in the strike bar; it helps to prevent the strike bar from catching on irregular surfaces.




The **Heel-Strike Mechanism** pulls on the cables when weight is placed on the heel.

The cables to be pulled are two sheathed cables laid out along the branches of the stirrup. The upper end of each cable is connected to one of the locking mechanisms, while the lower end is connected to the forward tip of the corresponding lever. When the wearer pushes the heel down onto the ground, the strike bar is pushed up against the strike-bar guide plates. This action pushes the tube-and-plunger assemblies upward, thereby pushing the rear ends of the levers upward. By the pivoting of the levers, this action pushes the forward ends of the levers downward, so that they pull on the cables. Longitudinal sliding of the plungers inside the tubes is resisted by overload springs, which thereby regulate the tension applied to the cables.

*This work was done by Neill Myers, Michael Shadoan, John Forbes, and Kevin Baker of* **Marshall Space Flight Center.** *For further information,* ***write in 39*** *on the TSP Request Card.*
*MFS-28992*

## Turning Threaded Fasteners Without Inducing Side Loads

Side loads are reacted via a structure surrounding the drive line.

*Marshall Space Flight Center, Alabama*

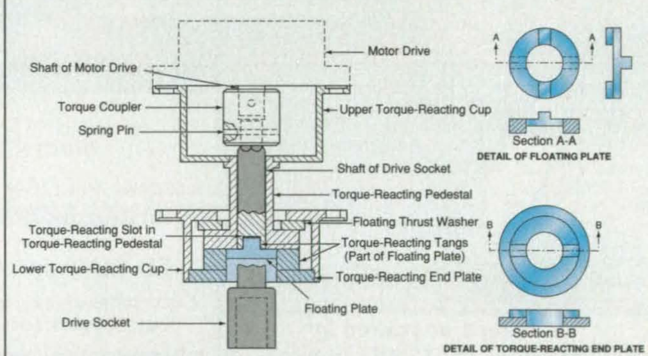
A tool has been designed to apply the desired torque to turn a nut or bolt around its longitudinal axis, without applying undesired side forces or tilting torques. In essence, a motor drive attached to the tool applies the desired torque to the shaft of a drive socket via the functional equivalent of a flexible shaft coupling, while an external tool structure that surrounds the shaft of the drive socket reacts incidental side forces and torques. The external tool structure

is braced to react the side loads away from the drive line.

The figure illustrates this principle of operation in more detail. The motor drive is attached to the flange on the upper torque-reacting cup. The shaft of the motor drive is coupled to the shaft of the drive socket via a torque coupler that resembles a conventional rectangular-to-hexagonal drive socket. A spring pin axially secures the shaft of the drive socket to the torque coupler.

Static reaction torque (tilting torque) is transmitted from the upper torque-reacting cup, to the torque-reacting pedestal, which is welded to the upper torque-reacting cup. A hole bored along the axis of the torque-reacting pedestal accommodates the shaft of the drive socket. Part of the shaft of the drive socket is shown broken away to expose the torque-reacting slot in the torque-reacting pedestal. This torque-reacting slot mates with the upper torque-reacting tang of the floating plate.

The torque-reacting pedestal and all parts attached to it (including the motor drive, the upper torque-reacting cup, the torque coupler, and the shaft of the drive socket) are free to slide horizontally along the upper torque-reacting tang of the floating plate. The hole in the flange at the top of the lower torque-reacting cup is made large enough to accommodate this sliding motion. The lower torque-reacting tang of the floating plate is oriented 90° away from the upper tang and mates with the torque-reacting slot in the torque-reacting end plate, which is welded to the lower torque-reacting cup; this feature allows the torque-reacting pedestal to also slide in the perpendicular horizontal direction and thus it can slide in any direction perpendicular to the vertical drive line. At the same time, the mating of the tangs and slots prevents rotation of the torque-reacting pedestal about the drive line.




This **Tool Applies Only Desired Twisting Torque** to a threaded fastener via the drive socket. The components surrounding the shafts transmit tilting torques and side forces to a bracing structure.

The static reaction torque can be transmitted from the lower torque-reacting cup via an interface fitting (not shown in the figure) to the bracing structure, which would ordinarily be the structure in threaded engagement with the fastener to be turned. The interface fitting is secured to the torque-reacting cylinder by bolting it to the flange of the lower torque-reacting cup.

*This work was done by Robert R. Belew of Boeing Co. for* **Marshall Space Flight Center.** *For further information,* ***write in 92*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-28925.*

# Estimating Peak Vibrational Stresses in Structures

A combination of measurement and computational techniques yields conservative approximations.

*Marshall Space Flight Center, Alabama*

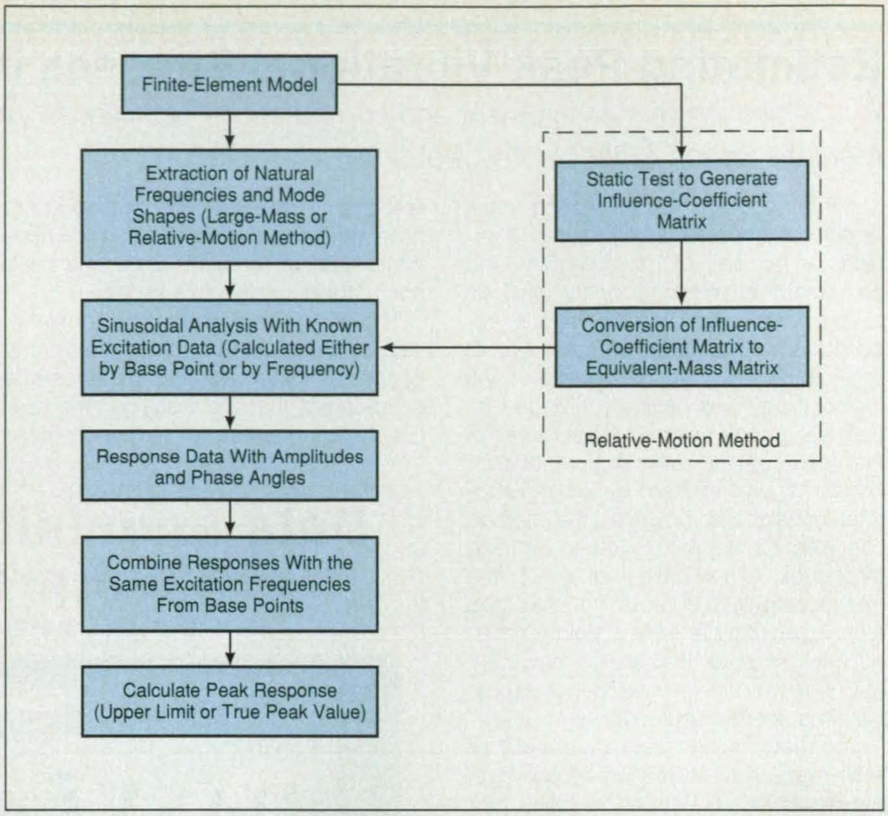
A methodology for estimating peak vibrational stresses in structures combines a number of measurement and computational methods for the analysis of sinusoidal vibrations at various frequencies, with regard for the limits of applicability of each technique. The methodology was originally intended for estimating peak stresses in structures of the space shuttle main engine, wherein vibrations are excited by turbopump-rotor imbalances; however, the method can also be applied to other vibrating structures. The main value of the methodology lies in providing alternative techniques that are likely to yield estimated peak stresses that are conservative, but no more conservative than is necessary in a specific application.

The methodology (see figure) involves finite-element mathematical modeling of the dynamics of a structure, using prescribed sinusoidal excitations of the base points of the structure. Any of three vibration-analysis methods can be integrated with the finite-element model. The methodology further involves the selection of either of two methods for calculating the peak stresses at the stress-component level in each element of the finite-element model.

The first vibration-analysis method, known as the large-mass method or the seismic-mass approach, has long been used for seismic analysis of such civil structures as multispan bridges. A large mass — several orders of magnitude greater than the sum of the diagonal terms in the mass matrix of the finite-element model of the structure to be analyzed — is lumped at each base degree of freedom (DOF) of the structure. Prescribed base accelerations are achieved in the base DOF directions by applying forces equal to the large masses multiplied by the corresponding prescribed accelerations. In some cases, the large masses used in the large-mass method can cause numerical difficulties during computation of vibrational modes; the large masses affect both accuracy and numerical conditioning, and must be adjusted in compromises that satisfy both of these criteria.

The second method is the relative-motion method, which can be used to analyze the dynamics of structures subjected to multiple base excitations. This method is, in general, free from numerical instabilities and yields correct computations of dynamic components of the response of the structure but does not account for the pseudostatic components that are present when one base point moves relative to another.

The third method is the pseudostatic-displacement method, which, as its name suggests, provides the pseudostatic components that are missing in the relative-motion method. In the pseudostatic method, one first calculates the dynamic components of the response by use of the relative-motion method, then combines these components with the pseudostatic components calculated from an influence-coefficient matrix and the sinusoidal motion prescribed at the base points. This method should yield the same estimate of total response as does




These **Procedures and Concepts** are used to estimate peak stresses in a structure that vibrates in response to sinusoidal excitations at multiple frequencies at multiple base points.

encountered in the large-mass method.

In a case in which multiple base points are excited at the same frequency, the response at each stress component in each finite element can be estimated extremely conservatively by simply adding the amplitudes of the responses to each base-point excitation. If information on the phases of the excitations and responses is available, then the degree of conservatism can be reduced by summing the responses according to their relative phases to obtain a composite amplitude and phase. The total response for each stress component in each finite element is obtained by summing the sinusoids, in the time domain, of the various frequency responses.

The two alternative methods for estimating the peak value of each stress component in each finite element are similarly straightforward. The most conservative of the two methods is the upper-limit method, in which one simply sums the amplitudes of the contributions from the various frequencies. The other method is the true-peak-response method, in which one either (a) numerically traces the computed total response as a function of time to find the peak or else (b) finds the time when the rate of change of the total-response sum of sinusoids is zero, then computes the instantaneous value of the total response at that time.

*This work was done by Lawrence K. Shen of Rockwell International Corp. for* **Marshall Space Flight Center.** *For further information,* ***write in 77*** *on the TSP Request Card. MFS-30090*

# Exoskeletal Apparatus Senses Motions of an Arm

## The apparatus can be used to provide control signals to a robot arm.

*Lyndon B. Johnson Space Center, Houston, Texas*

Figure 1 illustrates the use of an exoskeletal apparatus for measuring changing angular positions of shoulder and elbow joints. The joint-angle signals can be used to control a robot arm; that is, to make the robot arm imitate the motions of the wearer's arm. The joint-angle signals could also be used, for several other purposes; for example, to provide feedback for control of a virtual-reality or other interactive display, or to analyze shoulder and elbow motions for medical purposes.

The kinematic linkages of the appratus (see Figure 2) are designed for low inertia, light weight, comfortable attachment with a minimum number of parts, measurement of whole arm motions with a minimum number of sensors, and no kinematic singularities. The kinematic linkages are also designed, in conjunction with sensor-output-processing software, for simplicity of kinematic computations. The linkages can fit large and small arms without adjustment and they accommodate the natural small motions of centers of joints without inducing errors.

*This work was done by Bin An, Beth Marcus, and J. Kenneth Salisbury, Jr., of Exos, Inc., for* **Johnson Space Center.** *No further documentation is available.* *MSC-21971*

Figure 1. The **Exoskeletal Apparatus** is strapped to the wearer for measuring arm motions.

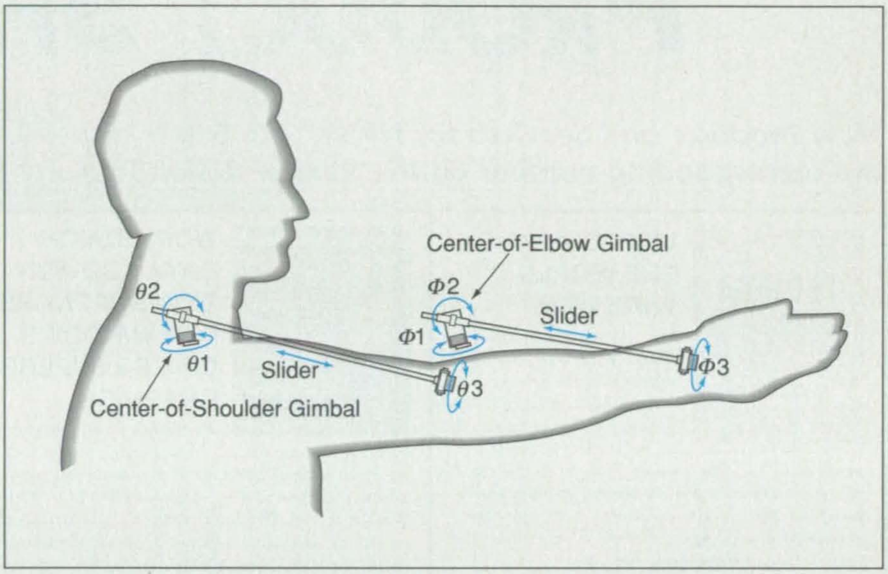



Figure 2. The **Apparatus Measures** shoulder-motion and elbow-motion angles.

# DESIGN ENGINEERING PRODUCT SHOWCASE

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**Omega Engineering Inc.**

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## WORKBENCH DATA ACQUISITION SOFTWARE FOR WINDOWS OFFERS SUPERB GRAPHICS

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**Omega Engineering Inc.**

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**Omega Engineering Inc.**

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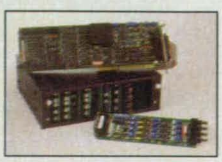

## DATA ACQUISITION BOARDS FOR DESKTOP PCS

Omega is proud to introduce the new DAQBOARD Series of PC/AT-compatible data acquisition and control boards. The DAQBOARD Series offers more signal conditioning choices than any comparable product, while also offering high-speed performance and a low cost. The unit features A/Ds, D/As, digital I/O, and counter/timers. A wide range of input types are available from thermocouples to strain gages. The unit may be expanded from 16 to 256 input channels.

**Omega Engineering Inc.**

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## OMJ SERIES TRANSDUCERS WITH BUILT-IN MODEMS

Utilizing a built-in modem, Omega's OMJ Series transducers transmit formatted data obtained from input sensors over standard phone lines to remote PCs. Units are self-powered by virtue of the phone line, and are FCC-approved. Models are available to measure temperature, pressure, 4-20 mA current loops, and tank level. The NEMA 4x corrosion-resistant 316 stainless steel housing makes it suitable for applications such as tank farms and pumping stations.

**Omega Engineering Inc.**

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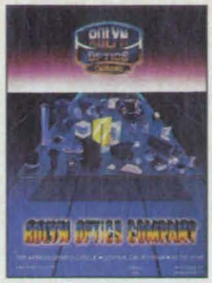


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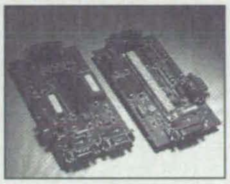

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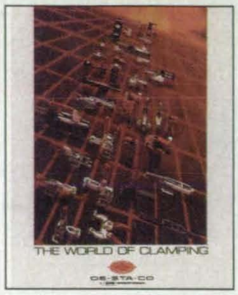


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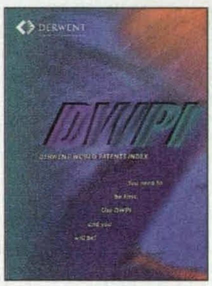


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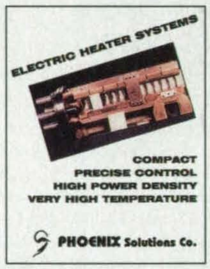


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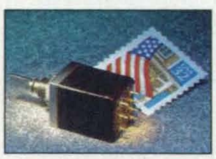

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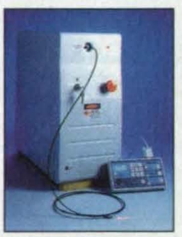

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For More Information Write In No. 331

# Laser Particle Counter Sensor

A new probe monitors particle contamination and improves semiconductor yields.

*Wright Laboratory, Manufacturing Technology Directorate, Wright-Patterson Air Force Base, Ohio*

Equipment operators are now able to monitor particle contamination inside a variety of semiconductor process machines using the new laser particle counter (LPC) system probe. The LPC sensor system is able to detect particle contaminants as small as 0.08 micron, and will result in a significant reduction in manufacturing defects on small-feature semiconductor devices.

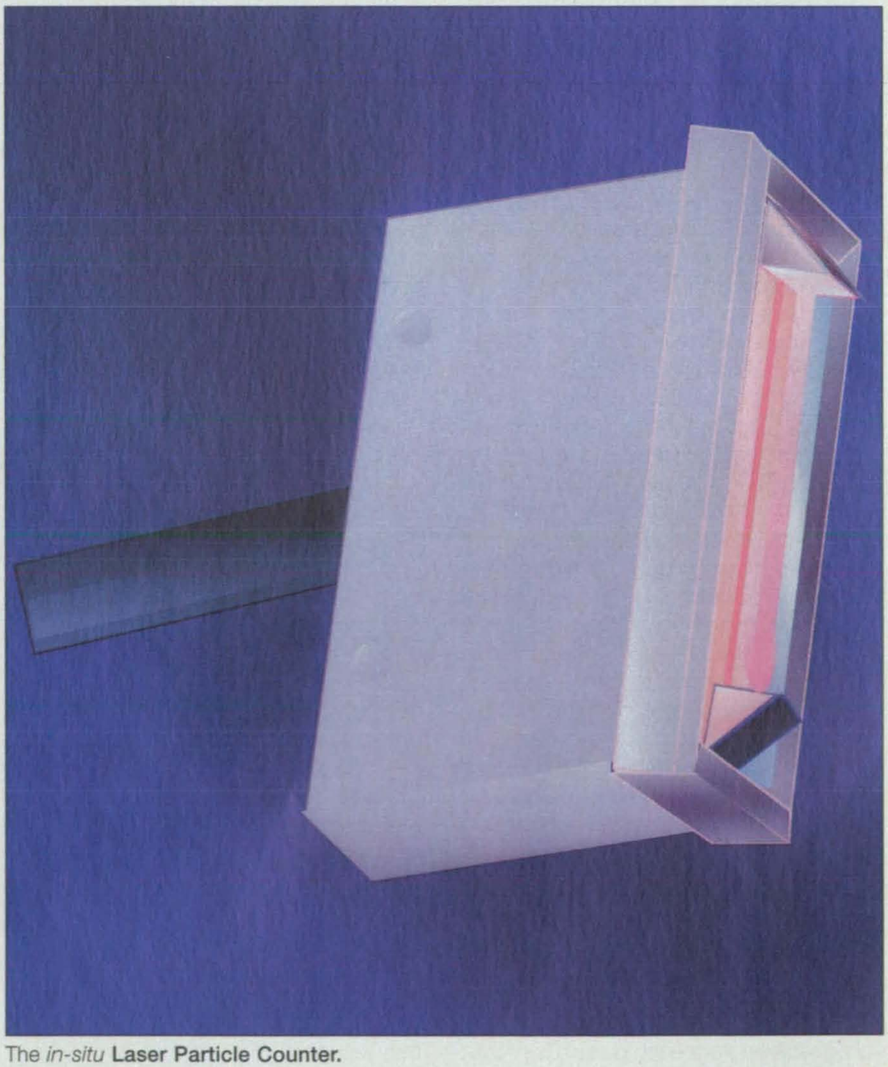
Under a program sponsored by Wright Laboratory's Manufacturing Technology Directorate, an LPC system using state-of-the-art optical and electrical components was designed, fabricated, and demonstrated.

Electronic components in weapon systems are becoming more complex and are packaged more densely. To meet future mission requirements, there is a continuing need to reduce the size and weight of electronic components. With the feature sizes in semiconductor integrated circuits becoming smaller as IC density increases, defects caused by small particles in the fabrication environment are becoming a greater problem and a source of increased product cost. In the past, 0.3-micron particles did not pose as large an obstacle to device yield as they now do with features as small as 0.5 micron.

One of the major sources of manufacturing defects on small-feature state-of-the-art devices is contamination from particulates generated within the IC fabrication equipment. Previously, high levels of small particles inside the process equipment were not thoroughly addressed. Such particles can be formed by sputtered or etch materials that dislodge from the vacuum chamber as it is evacuated or brought up to ambient pressure.

New *in-situ* sensors and control techniques were needed to provide methods to control the semiconductor manufacturing process to improve device yields. The application of advanced laser and fiber optic techniques to on-line particle monitoring in the process chamber was developed by Honeywell Sensor and System Development Center and successfully demonstrated in a Perkin Elmer 4400 sputtering machine. The LPC system's materials and design are compatible with high-temperature vacuum, radio frequency, and corrosive environments of existing semiconductor process equipment. It has built-in diagnostic and automatic sensitivity adjustments for aging or process damage.

*This work was done by Carlos Lizardi for* **Air Force Wright Laboratory**. *Inquiries concerning rights for the commercial use of this invention should be addressed to the Wright Laboratory Technology Transfer Office at (513) 255-2006.*



The *in-situ* **Laser Particle Counter.**

# Improved Multiple-Velocity-Component Laser Velocimeter

A modified signal processor enables the use of simpler optics.

*Ames Research Center, Moffett Field, California*

An improved laser Doppler velocimeter (LDV) measures two or even all three components of velocity of a sparsely seeded flow. In comparison to older multiple-velocity-component velocimeters that use multiple laser wavelengths, this one uses a single laser wavelength and fewer optical components, without sacrificing the quality of the measurements. Also, unlike other LDVs, in which a separate signal processor is needed for each component of velocity, this LDV contains only one processor, which extracts two or all three components of velocity. The result is a much less costly velocity measurement system.

In the improved LDV (see Figure 1), light from the laser is sent to a beam-waist-positioning lens, either through a single-mode optical fiber or directly through free space. Transmission through a fiber is usually preferable because it makes the LDV more easily adjustable and, therefore, more portable. In a typical older two-wavelength LDV, four single-mode optical fibers, each with its own coupler, are needed. Such couplers are expensive, adjustments of the couplers are time-consuming, and measurement errors can arise from variations in the lengths of the optical paths along the individual fibers. Thus, the design of this LDV saves considerable time in adjustment and eliminates this source of error.

After passing through the beam-waist-positioning lens, the laser beam impinges on a two-dimensional acousto-optical modulator (e.g., a Bragg cell), which both transmits part of the impinging beam unchanged and diffracts part of the impinging beam into two other beams that diverge in such a way as to define two orthogonal planes. The beams then pass through a transmitting lens, which causes the beams to intersect in a small crossover region centered at a common point. It is noted that the crossing of the laser beams at a common point is an inherent characteristic of the system shown in Figure 1; hence, no adjustment in the propagation directions of the individual laser beams is necessary. The beam-waist-positioning lens causes the waists of all the beams to lie at this common point; this ensures minimum spatial variation in the spatial frequencies of the interference fringes formed by the beams in the crossover region.

As the seeded flow passes through the crossover region, the seed particles scatter the light from the incident laser beams. The light scattered from each particle is modulated at a frequency proportional to each component of its velocity in each plane defined by a pair of intersecting laser beams and along a line perpendicular to the bisector of the beams. Collecting lenses focus some of the scattered light onto a multimode optical fiber, which conducts the light to a photodetector.

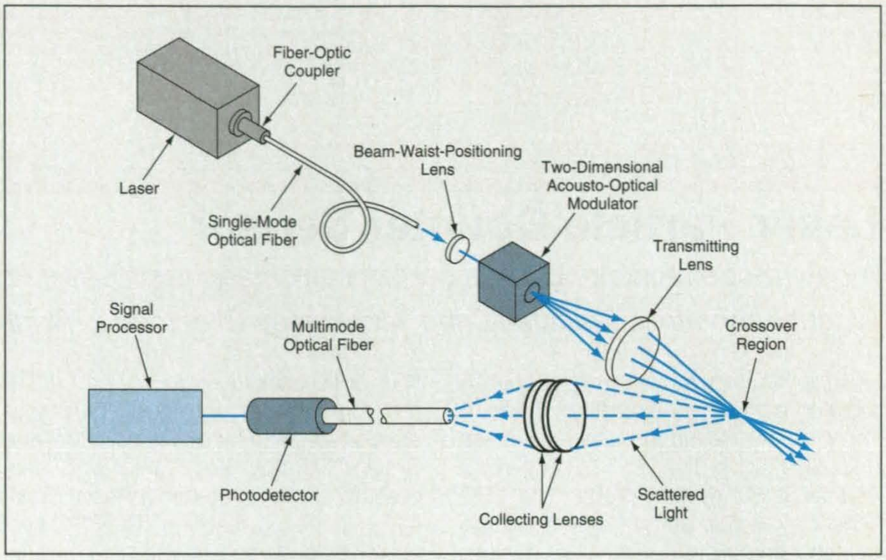



Figure 1. The **Improved Laser Doppler Velocimeter** operates at a single wavelength, with one signal processor, yet it can measure two or three components of velocity.

The output of the photodetector is sent to the signal processor, which includes an analog-to-digital converter, a discrete-Fourier-transform generator, and a frequency analyzer/separator (see Figure 2). Because the diffracted laser beams are generated by driving the two-dimensional acousto-optical modulator at different frequencies, the signal processor can extract the various components of velocity from the known relationships among the modulating frequencies and the orientations of the undiffracted and diffracted beams. Existing commercial LDV digital frequency processors can be modified to accommodate the spectrum of light scattered in this LDV.

Sensitivity to the third velocity component can be achieved by unlocking a third diffracted beam emanating from the Bragg cell. However, sensitivities similar to that for the other two velocity components would require the use of a second Bragg cell (a one-dimensional cell), optical fiber, transmitting lens, and the like, to generate an independent third beam pair with a different modulation frequency. Maximum sensitivity to the third velocity component would result when the bisector of this third beam pair was substantially orthogonal to the bisectors of the other of two laser beam pairs formed by the two-dimensional Bragg cell.

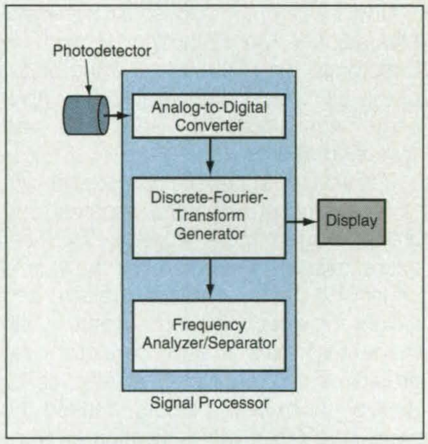



Figure 2. The **Signal Processor** in the improved laser Doppler velocimeter estimates two or three components of velocity from the scattered light by performing discrete Fourier transforms to extract the frequencies present, then computing the velocity from the known relationships among the components of velocity, the frequencies, and the directions of the diffracted laser beams.

*This work was done by Dennis A. Johnson of* **Ames Research Center.** *For further information,* ***write in 32*** *on the TSP Request Card.*

*This invention has been patented by NASA (U.S. Patent No. 5,526,109). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-11925.*

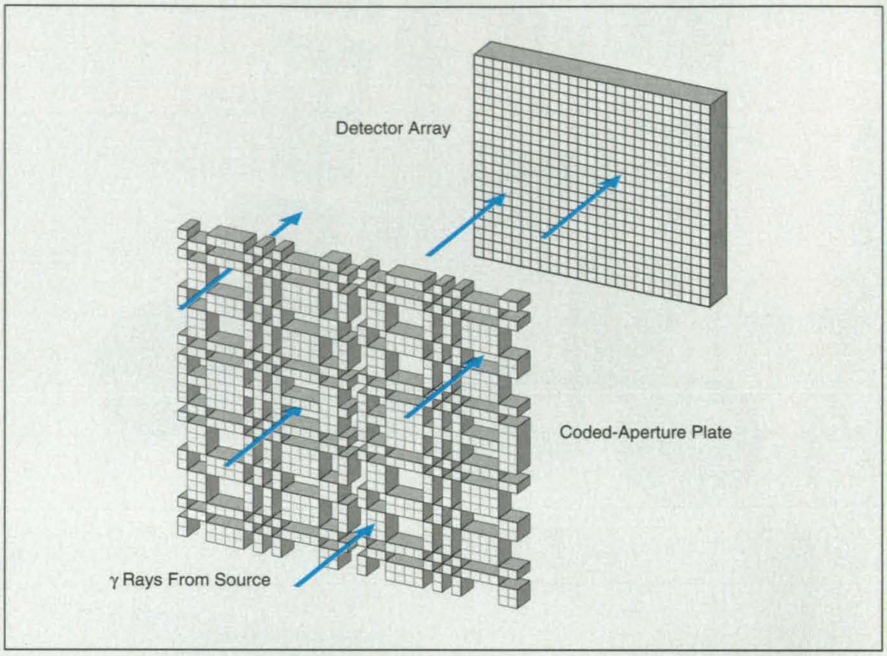
# Gamma-Ray Imaging With Two-Dimensionally-Coded Apertures

Relatively high spatial and spectral resolutions should be achievable.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A proposed g-ray-imaging instrument would provide both two-dimensional imaging at relatively high spatial resolution and spectroscopy at relatively high-energy resolution. The instrument (see figure) would include a large-volume germanium or silicon g-ray detector with an external electrode segmented into a rectangular array of distinct charge-collection regions, each of which would thus constitute one pixel or spatial-resolution cell. A coded-aperture plate containing a two-dimensional array pattern laid out on a rectangular grid identical to that of the detector would be placed between the detector and the g-ray source, with the grids aligned.

A similar instrument was described in "Gamma-Ray Imager With High Spatial and Spectral Resolution" (NPO-19140), *NASA Tech Briefs*, Vol. 20, No. 2 (February, 1996), page 49. However, the detector and aperture arrays in that instrument are one-dimensional and must therefore be rotated in synchronism about the nominal line of sight to obtain two-dimensional-image information. In the proposed instrument, there would be no need for such rotation.




The **Coded Apertures** would perform a function similar to that of the pinhole in a pinhole camera, except that it would not directly produce an image of the g-ray source; the detector outputs would have to be deconvolved to extract the image of the source.

In the proposed instrument, as in the previously reported instrument, the detector pixel outputs would be digitized, then sent to a computer for processing. Using a deconvolution algorithm based on the known geometric relationships among the g-ray source, the coded aperture, and the pixels, the computer would extract an image of the g-ray source from the digitized detector pixel outputs. The spatial resolution of the image could be increased by increasing the distance between the aperture plate and the detector. Both point and spatially extended g-ray sources can be imaged. Large fields of view could be obtained by use of multiple detectors.

*This work was done by John L. Callas, William A. Wheaton, and William A. Mahoney of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 25*** *on the TSP Request Card. NPO-19331*

# Principal-Component Analysis of Multispectral Images

Dominant physical processes can be displayed in vivid color-contrasted images.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The established statistical technique of principal-component analysis has been found to be useful in processing multispectral images to extract data on the dominant physical processes in a scene. Principal-component analysis is a linear technique that provides quick, vivid, and subtle quantitative results, using a moderate amount of equipment. The results of principal-component analysis of the input multispectral image data of a given scene are principal-component images, each principal-component image showing the spatial distribution of one of the dominant physical processes. The various principal-component images of a given scene can be rendered in different false colors and superimposed to provide vivid color-contrasted images. The initial application of this concept was to some astronomical images — specifically, selected images of Herbig-Haro objects, which are tightly grouped semistellar luminous knots. This concept may also prove useful in such other multispectral imaging applications as medical imaging and failure testing of materials.

Suppose that multiple input images of the same scene in $M$ different spectral bands have been obtained by placing different color filters in front of a charge-coupled-device (CCD) camera. Suppose that each CCD image contains $N$ pixels and that the pixels representing the same spatial points in the different spectral images have been registered with each other, then the first step in this application of principal-component analysis is to compute an $M \times M$ correlation matrix: Let $\sigma_{ij}$ be a measure

of the correlation between the *i*th and *j*th images, as given by

$$\sigma_{ij} = \left[ \sum_{n=1}^{N} I_{in} I_{jn} \right] - N\bar{I}_i\bar{I}_j$$

where $I_{in}$ denotes the brightness of the *n*th pixel in the *i*th image, $I_{jn}$ denotes the brightness of the corresponding pixel in the *j*th image, and $\bar{I}_i$ and $\bar{I}_j$ denote the average of brightness over all *N* pixels of the *i*th and *j*th image, respectively.

The next step is to compute the eigenvalues and eigenvectors of the correlation matrix $[\sigma_{ij}]$. Each eigenvector is an *M*-component vector, the components of which are weighting coefficients that are used to construct one of the principal-component images as a weighted sum (a linear combination) of the *M* input spectral images. In a matrix-vector representation of the process of construction of principal-component images, one can assemble the eigenvectors as row vectors in a new $M \times M$ matrix, represent the sets of original and principal-component images as column vectors, and represent the column vector of principal-component images as the product of the new matrix with the column vector of input spectral images:

$$\begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \\ \cdot \\ \cdot \\ \cdot \\ P_M \end{bmatrix} = \begin{bmatrix} \text{[eigenvector 1]} \\ \text{[eigenvector 2]} \\ \text{[eigenvector 3]} \\ \text{[eigenvector 4]} \\ \bullet \\ \bullet \\ \bullet \\ \text{[eigenvector } M\text{]} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ \cdot \\ \cdot \\ \cdot \\ I_M \end{bmatrix}$$

where $\mathbf{P}_i$ denotes the *i*th principal-component image and $\mathbf{I}_i$ denotes the *i*th input spectral image.

In the original astronomical application, four input spectral images of each scene of interest were recorded; one through a narrow-band filter centered at the Hα wavelength of 6,563 Å, one through a standard broadband visible-light filter called a "V" filter, one through a standard red ("R") filter, and one through a standard infrared ("I") filter. The principal components of different scenes that contain Herbig-Haro objects were found to be the same, and to be associated with physical processes; namely, component (a) is illumination from all sources, component (b) is red spectral-line emission from Herbig-Haro objects, component (c) is blue reflected light, and component (d) is Hα emission.

*This work was done by Karl K. Klett of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 96*** *on the TSP Request Card.* *NPO-19563*

# Portable Power System Monitor for Wide-Area Measurement

The system (PPSM) is the heart of the Wide-Area Measurement System being deployed in the power grid of the Western United States.

*Bonneville Power Administration, Vancouver, Washington, and Pacific Northwest National Laboratories, Richland, Washington*

The integrated Western power grid can be subject to dynamic disturbances and cascading outages, as exemplified by the recent system breakups on July 2 and August 10, 1996, which left dozens of cities and millions of people without power.

Utility experts believe these disturbances can be controlled or avoided. What is needed is a region-wide network of power-system monitors and analytical tools that give grid operators enough early warning of impending trouble that they can take remedial action.

Such a Wide-Area Measurement System (WAMS) is now being deployed in the Western system. Under joint DOE, EPRI, and WSCC (Western System Coordinating Council) sponsorship, 25 monitors have been installed from Canada to Arizona, and Colorado to California, with more to come.

The heart of this WAMS is the Portable Power System Monitor (PPSM) developed by the Bonneville Power Administration and Pacific Northwest National Laboratories. The PPSM monitors disturbances, interactions, and overall system state or conditions, particularly system dynamics in the frequency range of 0.1 to 10 Hz. These dynamics become increasingly problematic as transmission systems are more heavily loaded.

The PPSM is composed of off-the-shelf equipment and has a modular plug-and-play simplicity. Most PPSMs use Macintosh computers, but Pentium Pro computers are being readied for use as well.

The PPSM monitors system conditions continuously and stores data permanently when out-of-normal conditions are detected. Data is acquired, smoothed, and passed through software triggers. When a trigger occurs, a block of data surrounding the time tag of the trigger is permanently stored to disk as an "Event." The amount of pre- and post-trigger history that is saved can be set by the user.

Any combination of channels can be routed through seven different triggers: mean, deviation, standard deviation, oscillation, rate of change, step change, and bandpass. Data acquisition can also be set to trigger for a particular time of day, interval, or duration, as well as for local manual triggers and cross triggers (*i.e.*, triggered by other instruments on the system). Triggers can be set to see power quality limits, system instabilities, and other abnormalities. Cross-triggering allows the entire power system to be directly connected, since a trigger on one instrument can be set to trigger some or all of the others in the system.

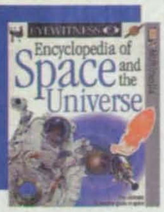
The PPSM now takes data in time scans, or blocks, of 5 seconds and passes it to a massive memory, which can be as large as needed or as small as the storage left on the system hard disk. The PPSM's circular buffer can contain up to 14 days of data from 96 channels at 20 samples per second, using a 4-Gbyte hard disk.

Each "Event" is given a "Title" containing the location, date, and exact time of its occurrence (*e.g.*, Event@MPVY 09/12/94 13H25m15s). This allows for a rapid and unambiguous search of data among thousands of "Events."

All data is time- and frequency-locked to UTC via the Global Positioning System

From the publishers of *NASA Tech Briefs*

# *Holiday Gift Ideas*

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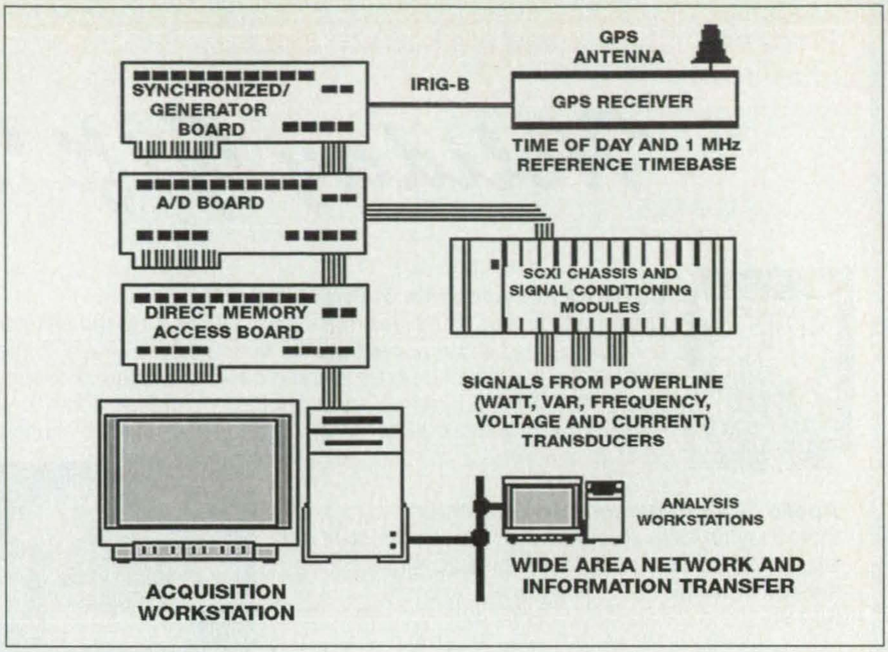
(GPS), so data from any part of the grid can be overlaid with any other data with an accuracy of 1 microsecond. (The capital H in the "Title" indicates the data is time-synchronized to UTC via GPS.)

WAMS has a highly networkable overall system concept. Its peer-to-peer Ethernet-type structure allows for connections at almost any level. Real-time or archived data at any monitor can be viewed from any other PPSM in the system. In addition, remote control software gives each PPSM the capability of controlling any other site. Software can be on- or off-loaded, triggering set, and the site viewed and controlled. As a result, remote sites need only be visited for hardware maintenance.

Three key software elements in the PPSM were written in LabVIEW at BPA: *DataTake*, *DataSee*, and *AutoDataSee*. *DataTake* is a multifunctional data acquisition component package that provides the user interface, configuration tools, memory management, and time and frequency synchronization. *DataSee* is used to view and analyze data, meld it with data from other PPSMs, and create all forms of data subsets. It allows row and column slicing, site-to-site record joining, moving data into other formats, printing, and both Prony and Gabor analysis. *AutoDataSee* allows any networked user to shear off data sets from one or more sites and join contiguous "Shears" into long data strings.

Using the PPSM's automatic connections to other power-system databases,




The **Portable Power System Monitor** is composed of transducers, signal conditioning, a GPS receiver, desktop workstation, and A/D, DMA, and timing boards (located within the computer) connected to a wide-area network.

users can append related information to "Event Titles," such as weather conditions, breaker status, system state data, and grid operator observations. Other software modules connect to and translate files from dissimilar data acquisition systems, such as the Macrodyne PMU and Hathaway DSM.

To date the PPSM has been successfully used for disturbance and system condition monitoring, model verification, commissioning tests, generator modeling, power quality monitoring at feeder substations, and sequence-of-event determination for major outages.

*This work was done by Dennis C. Erickson of the* **Bonneville Power Administration**, *and Matt K. Donnelly of* **Pacific Northwest National Laboratories**. *For further information call Dennis Erickson at (360) 480-2633 or Matt Donnelly at (509) 375-6826.*

# Characterizing Refractory Materials Through X-Ray Imaging

Ceramics and intermetallic-matrix composites can be evaluated.

*Lewis Research Center, Cleveland Ohio*

A report describes research on techniques for characterizing refractory materials by measuring attenuation of x rays and constructing images from such measurements. The materials in question are ceramics, intermetallic-matrix composites, metal-matrix composites, and ceramic-matrix composites, all of which are candidates for use in advanced high-temperature engines. The research was directed toward evaluating techniques with respect to their capabilities for revealing variations in densities and for use in monitoring accumulation of damage in, and failure mechanisms of, specimens of these materials during tensile testing. The research included the development of a point-scan digital radiographic system and an apparatus [described in "In Situ Radiography During Tensile Tests" (LEW-15684), *NASA Tech Briefs*, Vol. 18, No. 7 (July 1994), page 44] for taking x-ray film images of specimens while simultaneously acquiring stress and strain measurements. State-of-the-art x-ray computed tomography was also investigated. Point-scan digital radiography was found to be useful for characterizing variations in densities in monolithic ceramic specimens but time-consuming and of limited utility for characterizing ceramic-matrix composites. X-ray computed tomography was found to be useful for providing cross-sectional spatial density information on monolithic ceramics and metal-matrix composites. *In-situ* film x-radiography during tensile tests was found to yield information on damage mechanisms and accumulation of damage; combining it with pre- and post-test x-radiography was found to yield even more information that can lead to greater understanding of the mechanical behaviors of ceramic-matrix composites.

*This work was done by George Y. Baaklini of* **Lewis Research Center.** *To obtain a copy of the report, "Engine Materials Characterization and Damage Monitoring by Using X-Ray Technologies,"* ***write in 99*** *on the TSP Request Card.*

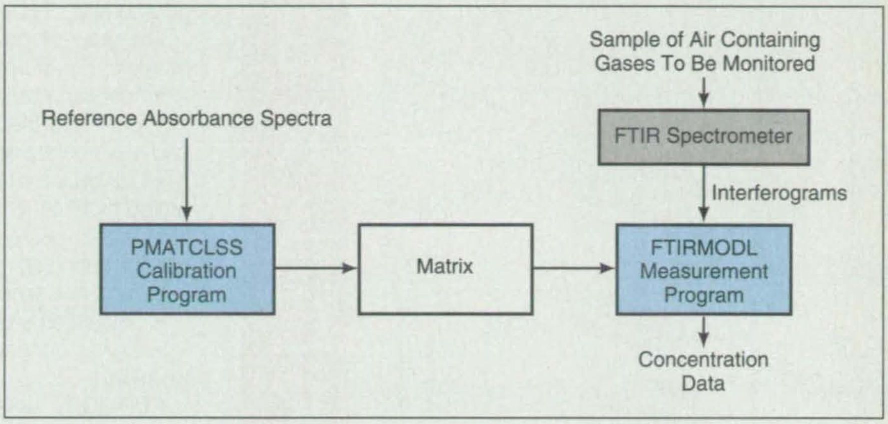
*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16285.*

# Software for Infrared-Based Vapor-Monitoring Instrument

A calibration program and an operating program are used together to obtain reliable measurements.

*John F. Kennedy Space Center, Florida*

Two computer programs have been written to provide a practical combination of automation and robustness in the measurement of concentrations of toxic vapors and other selected gases in air by a digitally controlled, digitally monitored Fourier-transform infrared (FTIR) spectrometer. These programs help to ensure accurate measurements despite drifting temperatures, degradation of optical components, and widely ranging, rapidly changing concentrations. The combination of hardware and software has been demonstrated to be capable of monitoring concentrations of hydrazines, ammonia, alcohols, chlorofluorocarbons, ketones, water vapor, carbon dioxide, and other gases in air. In addition, the pair of programs is adaptable to other spectroscopic concentration-measuring instruments, including those characterized by solid- and liquid-phase sample media and both reflective and transmissive measurement techniques.




The **Matrix Generated** by the calibration program is used by a measurement program. Interferograms acquired by measurement are processed with the matrix to yield data on the types and concentrations of vapors and other gases in the sample.

One of the programs, called "PMATCLSS," precalibrates the FTIR spectrometer. Written in the Pascal computing language, PMATCLSS employs a robust algorithm that makes allowances for wide fluctuations in environmental conditions and long periods between interventions by technicians. The user provides the program with a set of high-quality absorbance spectra for the chemical species expected to be present — including both the species that one seeks to monitor and other species that might give rise to interfering instrument readings. The user also tells the program what infrared frequencies are to be used for measurements and what concentrations were used to generate the reference spectra.

PMATCLSS produces a matrix which, when multiplied by a measured absorbance spectrum, gives the concentration(s) of the chemical species of interest in the sample (see figure). The matrix incorporates a least-squares fit to three shape functions that automatically correct the baseline data for changes in temperature and degradation of optics.

The other program, called "FTIRMODL," is written in the C language and performs the following functions:

- Acquires interferograms from the FTIR spectrometer,
- Converts the interferograms to single-beam transmittance and absorbance spectra,
- Classifies the absorbance spectrum by use of the matrix generated by PMATCLSS,
- Applies postcalibration curve data to linearize the reported concentration(s),
- Logs and time-stamps all concentrations thus determined,
- Calculates statistics on request, and
- Sends concentration data over a serial port to a central location.

FTIRMODL uses pipelining techniques to enhance throughput, enabling it to compute concentrations in nearly real time. It interleaves the acquisition of interferograms with processing of interferograms acquired previously, so that the instrument can always be scanning. Measurements are produced at regular time intervals ranging from 2 to 30 s, depending on the particular vapor being monitored.

Both programs can be executed on DOS-based personal computers. In addition, FTIRMODL has been demonstrated on an embedded controller that fits neatly within the FTIR spectrometer.

*This work was done by Paul A. Mogan and Dale E. Lueck of* **Kennedy Space Center** *and Christian J. Schwindt and Carl B. Mattson of I-NET. For further information,* ***write in 8*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11699.*

## Return-Beam Derotator for Conscan Doppler Laser Anemometer

### A rotating prism would introduce an orbiting countertilt and counterdisplacement.

*Marshall Space Flight Center, Alabama*

An optomechanical derotator has been proposed to compensate for the inherent angular lag between the outgoing and return beams in a conical-scan (conscan) Doppler laser ranging system of the type used to measure winds at distant locations in the atmosphere. It would be desirable for the outgoing and return beams to travel along the same optical path, but this cannot happen unless the system scans impractically slowly. At a practical scan rate, a small but significant angular lag arises because of the finite speed of light: during the time it takes light to make the round trip between the system and the target region, the conical scan continues, so that upon the return of light scattered from the target, the system is aimed in a slightly different direction.

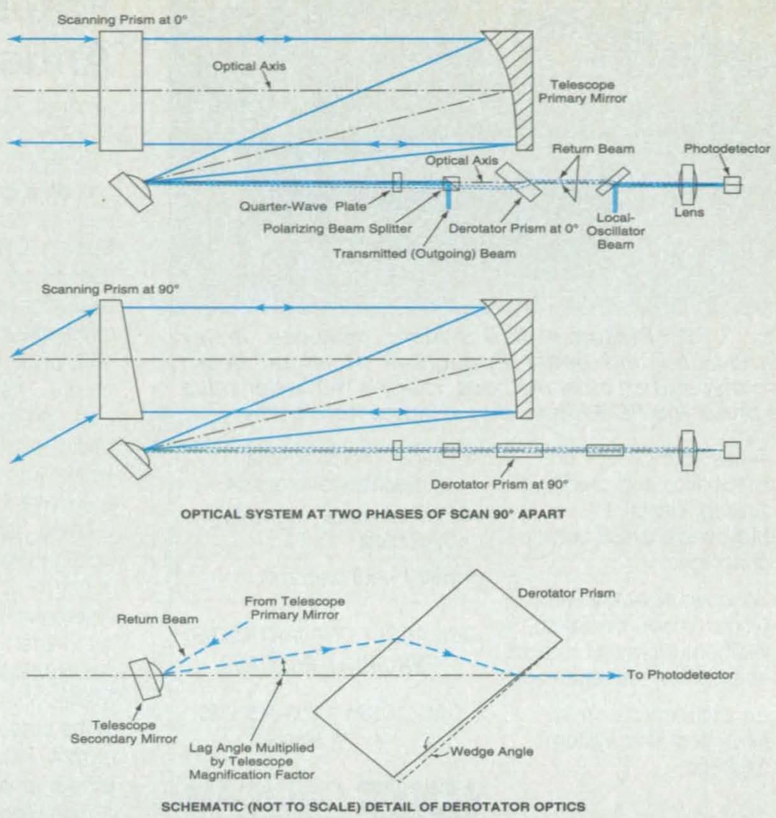
The figure schematically illustrates the optical layout. The outgoing light is transmitted, and the return light is received through a reflecting telescope. The conical scan is effected by use of a rotating prism at the outer end of the telescope. Nominally, the return beam is sent back through the system optics along the same optical axis as that of the outgoing beam, until it reaches a photodetector. A local-oscillator laser beam is also sent to the photodetector along the optical axis, and the Doppler shift in the return beam (manifested as the difference between the frequencies of oscillation of the two beams) is extracted by heterodyne detection. Precise superposition of the local-oscillator and return beams is essential for efficient heterodyne action, but because of the angular lag, the beams are not precisely superimposed; instead, the return beam is tilted by an amount proportional to the angular lag, is slightly laterally displaced from the axis, and orbits about the axis in synchronism with the conical scan.

The derotator would impose a compensating tilt and lateral displacement to bring the return beam back to the optical axis. The optical element of the derotator would be a high-index-of-refraction, windowlike prism with two flat window surfaces at a slight wedge angle with respect to each other. The derotator prism would be placed on the optical axis, with the perpendicular to one window surface at an angle of 45° to the optical axis and in the plane defined by the return beam and the optical axis. To maintain this relative orientation, the derotator prism would be rotated about the optical axis in synchronism with the conical scan and the orbiting of the return beam.

The wedge angle would be chosen so that by the combined effects of refraction of the return beam at entrance and exit window surfaces, the return beam would be bent back parallel with the optical axis. The thickness of the derotator prism would be chosen so that the refraction at the entrance window surface and the resulting tilt of the beam within the derotator prism would displace the return beam laterally, back toward the optical axis, just enough so that the return beam would leave the derotator prism on the optical axis. The wedge angle and thickness to satisfy these requirements can be computed straightforwardly in terms of the magnification of the system telescope, the angle of the scanning cone, the rate of scanning, the distance to the target, the distance from the secondary mirror of the telescope to the prism, and the index of refraction of the derotator prism.

*This work was done by Michael J. Kavaya of* **Marshall Space Flight Center** *and Farzin Amzajerdian of the University of Alabama in Huntsville. For further information,* ***write in 97*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26395.*




The **Derotator Prism Would Be Rotated** in synchronism with the conical scan and with the consequent orbiting of the return beam about the optical axis. The dimensions and orientation of the prism are chosen so that at the exit face of the prism, the return beam coincides with the optical axis.

# Patent Statement on the Anderson Current Loop

*Ames Research Center, Moffett Field, California*

A report consisting of the main text of U. S. Patent 5,371,469 presents detailed information on electronic instrumentation circuits of the type described previously in "The Anderson Current Loop" (DRC-00001), *NASA Tech Briefs*, Vol. 18, No. 12, (December 1994), page 30. To recapitulate: These circuits are excitation-and-signal-conditioning circuits suitable for use with strain gauges, resistance thermometers, and other electrical-resistance transducers that may be mounted in harsh environments. These circuits are based on the four-wire-probe concept and can be used as alternatives to Wheatstone bridges. The basic idea is to connect an electrical-resistance transducer in series with a reference resistor of nominally equal resistance via the current probe wires, excite the series circuit with a known current, sense the voltages across the two resistances via the voltage probe wires, and measure the difference between these voltages (for example, by use of instrumentation amplifiers in a differential-voltage-amplifying configuration with output terminals connected to a voltmeter). Circuits of this type simplify the signal-conditioning problem in that they enable precise measurements of small changes in the resistances of transducers, even in the presence of parasitic impedances in connecting wires. The output voltages of these circuits are highly linear — essentially proportional to the resistance changes to be measured.

*This work was done by Karl F. Anderson of* **Ames Research Center.** *To obtain a copy of the report, "Constant Current Loop Impedance Measuring System That Is Immune to the Effects of Parasitic Impedances,"* ***write in 85*** *on the TSP Request Card.*

*This invention has been patented by NASA (U.S. Patent No. 5,371,469). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-13376.*

# Modulated-Source Interferometry

Advantages of monochromatic- and white-light interferometry are gained without incurring the disadvantages.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Modulated-source interferometry is an improved interferometric method that involves the use of coherent monochromatic light amplitude-modulated at the source by a signal of radio or higher frequency. This method offers the advantages of both conventional monochromatic-light and conventional white-light interferometry, without the disadvantages of either. Modulated-source interferometry is applicable to a variety of applications, including long- and short-range metrology, stabilization of laser frequency, analysis of polarization states, splicing of high-birefringence phase-modulating optical fibers, alignment of polarization of light incident upon birefringent media, monitoring of crystal growth, three-dimensional imaging of surfaces, and measurements of attenuation, reflectivity, and optical thickness.

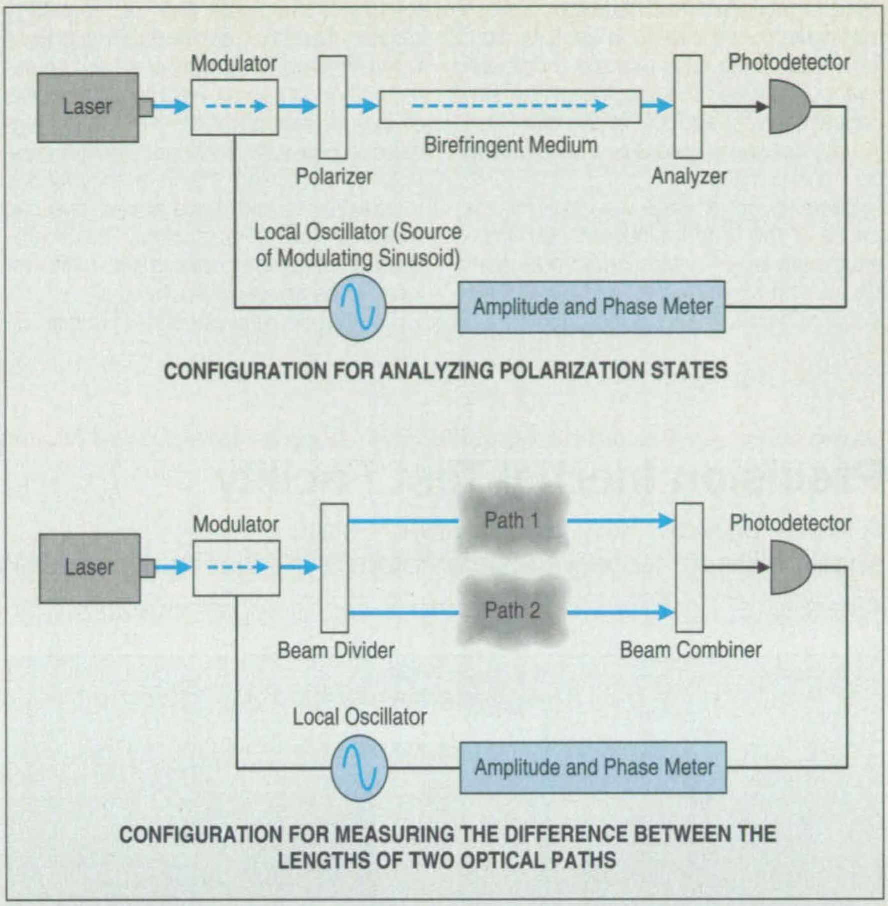
The advantage of conventional monochromatic-light interferometry is that it enables precise measurement of relative phase changes or displacements (by counting the passage of interference fringes); the disadvantage is that because of the inherent ambiguity in the absolute number of fringes (the fundamental integer-multiple-of-$2\pi$ phase ambiguity), it gives no information on absolute phase changes or displacements. The advantage of white-light interferometry is that it can provide absolute measures of optical-path lengths; the disadvantage is that the measurements are restricted to very narrow ranges.

The figure illustrates two of many possible configurations for modulated-source interferometry. In both configurations, light from a laser is amplitude-modulated at a suitable frequency, yielding a laser beam that includes a carrier signal (at the original laser frequency) plus two sideband signals (at frequencies above and below the carrier frequency by an amount equal to the frequency of the modulation). The modulation can be regarded as converting the monochromatic laser light into quasi-white light in a very narrow wavelength band. After this point, the two configurations begin to differ.

The first configuration is typical of a setup for analyzing polarization states. In this configuration, the beam passes through a linear polarizer, then enters a birefringent medium, where the beam is effectively split into two beams, each being in one of the two polarization eigenmodes of the medium. The optical axis of the medium is oriented perpendicular to the direction of propagation of the light. Where the two beams leave the medium, they are combined by an analyzer (another linear polarizer), then coupled into a photodetector with a response time appropriate to the frequency of modulation.

The second configuration is typical of a setup for measuring the difference between the lengths of two optical paths. In this configuration, the laser beam is split into two beams, each of which travels along one of the two optical paths to a beam combiner. The output of the beam combiner is then coupled into a photodetector as before. In both configurations, the output of the photodetector is a sinusoid of the same frequency as that of the modulation applied to the source. The amplitude of the photodetector output is measured and its phase relative to that of the modulating signal is measured.

This amplitude and phase depend on the optical phase difference between the two paths, the phase difference between the two paths at the modulation frequency, the intensities (not necessarily equal) of the two beams, and the relative intensity of the light analyzed from each of the two paths. In the first configuration, the phase differences depend on the length of the path through the birefringent medium and the difference between the indices of




These **Two Optical Configurations** are typical of those that can be used in modulated-source interferometry.

refraction for the two polarization axes of the medium; in the second configuration, the phase differences depend on the difference between the lengths of the two optical paths in addition to the difference (if any) between the indices of refraction on the two paths.

Because of a large variation in the phase of the output sinusoid with differential path length that occurs under conditions that minimize the amplitude of the sinusoid, modulated-source interferometry offers the potential for sensitivity greater than that achievable in conventional interferometry. Moreover, at differential path lengths that are integer multiples of the wavelength of the modulating signal, the peaks in this phase variation disappear. By tuning the frequency of the modulation to find these points, one can measure distances accurately. The sharpness of the phase peaks is also useful for locking the frequencies of lasers.

*This work was done by Roman C. Gutierrez of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 31*** *on the TSP Request Card.*

*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 Resident Office–JPL; (818) 354-5179. Refer to NPO-19418.*

# Precision Inertial Test Facility

A facility provides very precise steady-state acceleration for testing accelerometers and other inertial devices.

*AlliedSignal Federal Manufacturing & Technologies, Kansas City, Missouri*


Figure 1. The **Centrifuge** runs on an air-bearing inside a containment vessel. The access door is shown open, with the rotor visible.

This system was originally designed to test an acceleration-sensing component for the Arming, Fuzing, and Firing Assembly for the Trident II fleet ballistic missile. Potential applications include function testing and characterization of accelerometers as well as correlation studies for inertial devices done to a high degree of repeatability. The facility consists of two major subsystems: a centrifuge and an indexer.

**Centrifuge:** This is the most precise centrifuge system available for steady-state acceleration. It uses a cushion of air. This system is capable of steady-state accelerations precise to 50 parts per million from 1 to 150 g. The centrifuge is also capable of positioning its rotor in controlled movements to 0.001 degree of rotation for taking bias measurements on the unit under test. The plane of rotation is held level within 10 arcseconds.

There are six test positions on a 27.5-inch radius, and each has a capacity for units up to 15 lb. A full complement of slip-ring channels allows for power to be supplied to and signals to be taken from the unit under test. The 2000-lb. rotor is conditioned to 65 °F during testing.

Rotor stretch, due to centripetal acceleration, causes the effective radius at the unit under test to change slightly as a function of speed. This error has been fully characterized using a laser interferometer and is compensated for in the control system. Multiple interlocks prevent out-of-balance conditions as well as other conditions to protect the equipment and its operator. The backup gas supply for the bearing is bottled ultra-high-purity nitrogen. In the event of a loss of air supply during testing, the nitrogen is automatically turned on and mechanical brakes are set to stop rotation.

**Indexer:** This is a two-axis indexer capable of presenting the unit under test at various angles relative to Earth's gravitational acceleration within +/-3 arcseconds. A full 360 degrees of tilt and rotation are available. Temperature is controlled in the test chamber to within +/-1 °F. Units under test can be subjected to

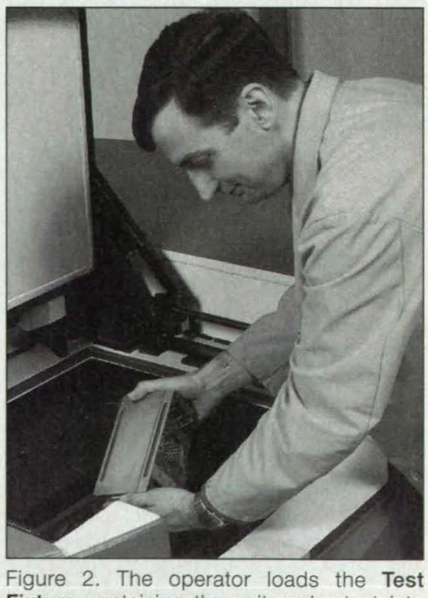


Figure 2. The operator loads the **Test Fixture** containing the unit under test into one of the six test positions on the rotor.

temperatures of 60-140 °F during functional testing. There are six sites for test units on the indexer.

Both systems are computer-controlled so that test stimulus, data acquisition, indexer, and centrifuge control are handled automatically.

*This work was a joint effort between* **AlliedSignal Federal Manufacturing & Technologies** *and* **Sandia National Laboratories.** *AlliedSignal Federal Manufacturing & Technologies is operated for the United States Department of Energy under contract no. DE-AC04-76-DP00613. Some of the individuals responsible are Richard E. Markley (retired), Alan L. VanDeusen, and Steven F. Prewitt of AlliedSignal, Kansas City, MO, and James R. Kannolt, Dan A. Murphy, Mike S. Rogers, and Gerry A. Wymer of Sandia National Labs, Albuquerque, NM.*

*Inquiries about accessing this test facility should be directed to Caron Fisher at*

Figure 3. The **Tester Control Room** houses the consoles for controlling the centrifuge, the indexer (shown at the right of the photo), and the stimulus to the unit under test.

*AlliedSignal FM&T, 2000 East 95th St., Kansas City, MO 64131-3095; 1-800-225-8829.*

# Reference Substrates for Overlay- and Linewidth-Instrument Calibration

Conducting features are replicated in single-crystal films formed on an insulating material.

*National Institute of Standards and Technology, U.S. Dept. of Commerce, Gaithersburg, Maryland*

This NIST invention provides an improved test structure for measuring width, spacing, or similar geometrical characteristics of conductive lines formed on substrates in semiconductor fabrication. The method enables the calibration of instruments used for such measurements.

Starting with a monocrystalline substrate, such as a silicon wafer having a specified crystal orientation, researchers form an insulative silicon dioxide layer beneath its surface by ion implantation or an equivalent process. The surface layer is then patterned by standard photolithographic techniques. Next an etchant removes the monocrystalline material along the crystal planes, leaving a conductive structure with accurately defined planar features whose angles and dimensions are known. Electrical testing (current-forcing, voltage-drop electrical measurements as well as capacitive, inductive, or impedance measurements) can then certify the structure's geometric characteristics, from which other instruments can be calibrated.

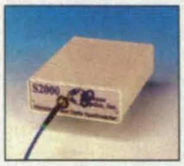
Furthermore, the underside of the substrate can be selectively removed beneath the insulative glass layer to form a transparent window, which allows correlative measurements by optical, electrical, and scanning probe microscopy instruments.

This invention improves the accuracy and reliability of manufacturing processes by taking advantage of the crystal alignment of the substrate as a guide to etch reliably uniform planar conductive patterns. It eliminates a previously required theoretical step of modeling to determine the likely location of the edges of a line. The invention allows the cross-calibration of imaging instruments such as electron and scanning probe microscopes, eliminating earlier cross-correlation errors due to line irregularities.

The invention will particularly benefit integrated-circuit manufacture and testing as the more demanding production technologies of miniaturization continue to increase.

*This work was done by Dr. Michael Cresswell of the* **National Institute of Standards and Technology.** *The invention has been reduced to practice. A patent is pending, and exclusive and nonexclusive licenses are available. Licensing inquiries may be directed to Marcia Salkeld, Licensing Assistant, NIST, Department of Commerce, Building 820, Room 213, Gaithersburg, MD 20899-0001; (301) 975-4188; FAX (301) 869-2751. Refer to NIST Docket No. 95-009CIP.*

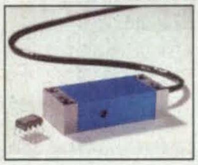
# NEW PRODUCTS



### Miniature Fiber Optic Spectrometer

Ocean Optics, Dunedin, FL, adds the S2000 to its line of low-cost miniature fiber optic spectroscopic instruments. The sensitivity has been increased to 86 photons/count (2.9 X $10^{-17}$ joule/ or watt/count), but the price remains $1800. The S2000 has a compact optical bench coupled to a 2048-element CCD linear array detector, making it suitable for low-light-level applications. There are 14 grating choices, optimized for UV, VIS, or near-infrared. Resolution ranges from 0.1-10.0 nm (FWHM) depending on groove density. Applications include chlorophyll analysis, oxygen sensing, plasma monitoring, and pharmaceuticals testing.

**For More Information Write In No. 800**



### Holographic Linear Encoder System

The ZPE-100R zero path encoder from Opti-Cal, San Luis Obispo, CA, is a non-contacting holographic linear system that works by reflection using a temperature-controlled laser diode. Sine and cosine outputs cycle for a signal period of 0.8 micron, and digital quadrature outputs yield 0.2 micron/count. Overall repeatability is better than 0.01 micron, and absolute accuracy better than 5 ppm. Optional high-speed interpolation circuitry provides 0.01 micron count or finer. Other options include counters and computer interfacing. Applications include astronomy, optical recording, and IC test equipment. Prices start at $1500.

**For More Information Write In No. 804**

### Electronic Measuring Systems

The LOGIC electronic measuring systems (EMS) from Chicago Dial Indicator, Des Plaines, IL, consist of linear probes in seven travel ranges and remote LCD readouts featuring five selectable resolutions in English or metric. Absolute/preset measuring mode covers a preset number range up to 99.99995. Total indicator reading (TIR) allows the user to continuously display the difference between the highest and lowest measurements. Hold features include minimum, maximum, and freeze hold. The company cites machine and turning centers, QC rooms, and floor inspection stations among applications.

**For More Information Write In No. 807**

### Aerosol Particle Counter for Cleanrooms

The line of LASAIR™ optical particle counters from Particle Measuring Systems, Boulder, CO, is designed for contamination monitoring in cleanroom facilities. The aerosol instruments use a passive laser cavity and sample flow cell as an integral assembly easily removed for servicing, the company says. Minimum sizing thresholds available are 0.1, 0.2, 0.3, and 0.5 micron at sample flow rates from 0.002-1 CFM. FS209E air cleanliness certification is available, along with an optional 3.5-in disk drive and electroluminescent CRT display.

**For More Information Write In No. 810**

### Digital Sampling RF Power Meter

The Model 4230 RF power meter from Boonton Electronics, Parsippany, NJ, samples at up to 200 readings per second, measures power from -70 to +44 dBm, and covers 10 kHz to 100 GHz. Sensor calibration data, resident in the data adapter, is automatically downloaded to the meter when the sensor is connected, eliminating the need for manual sensor setup. It comes with either an RS-232C serial communications interface or IEEE-488 GPIB. Dual channels and built-in math-processing capability make possible simultaneous input and output power measurement.

**For More Information Write In No. 801**

### Single-Column Materials Test Systems

Instron Corp., Canton, MA, introduces single-column models in its 4400 and 5500 families of low-force materials testing systems. Available with capacities of 112, 225, or 450 lb. (0.5, 1, or 2 kN), the systems can measure tensile, compression, shear, peel, and flexural quantities. Among materials that can be tested are textile threads, wire, plastic, paper, elastomers, rubber, and more. Each family has three load frame capacities with interchangeable load cells, extensometers, and test fixtures.

**For More Information Write In No. 805**

### Pressure Transducer with Two Active Parts

The XKP 1260 pressure transducer from Integrated Sensor Solutions (ISS), San Jose, CA, has only two active components: a custom IC for signal processing and a stainless steel sensor element. It has accuracy of ±1.5 percent over the temperature range of -20 to +85 °C, and operating range from 100-10,000 psi. Its electronic trimming for calibration and temperature compensation, the company says, means greater accuracy and long-term reliability. ISS says the XKP 1260 is well suited for monitoring the pressure of fluids compatible with PH-17 stainless steel in heavy-duty vehicles and industrial applications.

**For More Information Write In No. 808**

### Large-Scale Roundness Measurement

The Talyrond 4 from Rank Taylor Hobson Inc., Rolling Meadows, IL, with a load capacity of 1000 kg (2200 lbs.), is capable of providing automatic sequential geometric analysis of large or awkward components. Able to measure in both the rotational and vertical axes, it has automatic centering and leveling capabilities, and can measure roundness, vertical straightness, squareness, flatness, parallelism, coaxiality, cylindricity, harmonics, slope, and associated parameters. The radial gauging assembly is carried on a motorized column that allows measurement of components up to 1000 mm in height.

**For More Information Write In No. 811**

### Laser Power and Wavelength Measurement

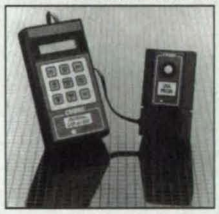
Two new measurement heads for the OMM-6810B optical multimeter from ILX Lightwave, Bozeman, MT, can measure optical power from -40 to +30 dBm (0.1 µW-1 W). The instruments can also supply simultaneous wavelength measurement, useful when monitoring laser diodes and tunable sources. The OMH-6722B covers the measurement range from 400-1100 nm, and the OMH-6727B from 950-1650 nm. Accuracy for the heads are ±3.5 percent for power and +/-0.5 percent for wavelength. The OMM-6810B has a 6-digit display, and is available with an optional IEEE-488.2 GPIB interface.

**For More Information Write In No. 802**

### Ultrashort Laser Pulse Characterization

FEMTOS from Polytec PI Inc., Costa Mesa, CA, is a microprocessor-controlled modular system capable of measuring ultrashort pulse parameters with simultaneous spectral and time resolution. Equipped with a correlator, spectrometer, and time-delay function, it operates in single-shot mode with low pulse energy (0.1 nJ), in fast-scanning mode, and with step-by-step adjustment of delay lines. A simple manual adjustment converts the system into one for pump/probe pulse experiments (delay time ±300 fs to ±40 ps). The smallest increment is 1 fs.

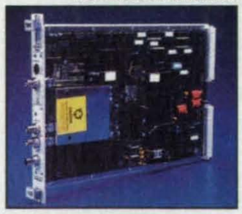
**For More Information Write In No. 806**



### Handheld Radiometric Measurements

The Goldilux™ Smart Meter/Probes from Oriel, Stratford, CT, are fully automated so that the user is ready for radiation measurement after just connecting the Smart Probe to the meter. They accept external radiometric probes for UVA, UVB, and UVC measurements and photometric probes for 380-760 nm. The meter reads calibration information and probe identification, providing calibrated readings in appropriate units. Measurements and display data can be set using the front-panel controls and an alphanumeric LCD screen, or accessed through an interface and a PC.

**For More Information Write In No. 809**



### 200-MHz VXIbus Counter/Timer

Racal Instruments Inc., Irvine, CA, introduces the 2251A counter/timer compatible with the VXIbus test standard. Despite its small single-slot C-size footprint, it offers 12 high-resolution measurement functions, including phase and pulse parameters. The 2251A provides A and B inputs to 200 MHz for universal functions, and an optional C channel for frequency measurement to 1.3 GHz. The VXI analog sumbus can be used as an input to channel A, which can be commoned with channel B to measure pulse width and rise and fall times.

**For More Information Write In No. 812**

# Machinery/Automation

## Generation of Helical Gears Modified To Reduce Vibrations

Modified grinding wheels would be moved along modified trajectories.

*Lewis Research Center, Cleveland, Ohio*

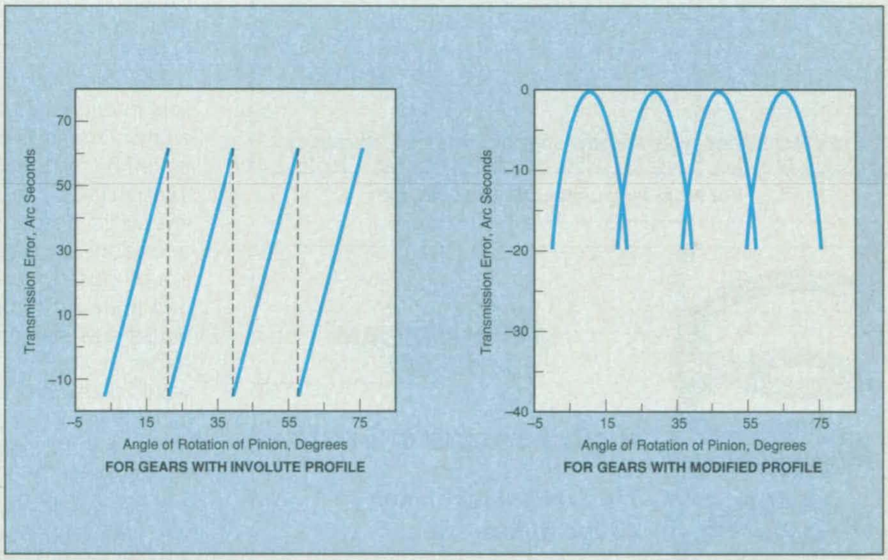
Helical gear teeth modified to reduce transmission errors (and thus vibrations) would be fabricated in a form-grinding process, according to a proposal. The proposed gear teeth were described in "Helical Gears Modified To Decrease Transmission Errors" (LEW-15048), *NASA Tech Briefs*, Vol. 17, No. 10 (October, 1993), page 102. To recapitulate: The modified gear-tooth surfaces differ slightly from the involute profiles that are the nominal profiles of conventional gears.

Involute profiles yield perfect meshing (zero transmission error) when gears are perfectly aligned and carrying no load, but when gears are misaligned, contact points shift to the edges of the gears, giving rise to transmission errors (and thus vibrations), the magnitudes of which increase sharply from zero with increasing amount of misalignment. The proposed modifications of the profiles would introduce some small irreducible transmission errors even when the gears were perfectly aligned. However, contacts would be localized away from edges, and transmission errors would increase much less and retain the desired parabolic shape (see figure).

A modified gear-tooth surface would be generated by use of a grinding wheel positioned by a computer-numerically-controlled machine with five degrees of freedom, with indexing of the gear being formed. The shape and the trajectory of the grinding wheel would differ slightly from those used to generate the corresponding involute profile; the differences in shape and trajectory would depend on the required differences between the tooth surface and the involute profile. The precise shape and trajectory would be computed as nonlinear functions that express the relationships among the motion of the tool, the motion of the gear, and the surface to be generated.

*This work was done by F. L. Litvin, N. X. Chen, and C. L. Hsiao of the University of Illinois at Chicago and R. F. Handschuh of the U. S. Army Vehicle Propulsion Directorate for* **Lewis Research Center.** *For further information,* ***write in 71*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16191.*




**Transmission Errors** (deviations of the output shaft angle from strict proportionality to the input shaft angle) were computed for a representative pair of helical gears with shafts crossing (misaligned) at an angle of 5 arc minutes, with and without the modified gear-tooth surfaces.

## Reducing Blade/Vortex-Interaction Noise From Rotorcraft

Net flows through rotors are increased to sweep away blade-tip vortices.

*Ames Research Center, Moffett Field, California*

Several alternative mechanisms have been proposed for reducing the noise, called "blade slap," that helicopters and tilt-rotor aircraft emit during some flight maneuvers. All of the proposed mechanisms are based on the principle of modifying the flow of air about a lifting rotor to increase the separation between (a) the wake shed by each rotor blade and (b) the following rotor blade(s).

Blade slap is also known as blade/vortex-interaction (BVI) noise. Each rotor-blade tip sheds a vortex, which can remain in the vicinity of the rotor or be swept away, depending on the details of the airflow in the vicinity of the rotor. BVI noise originates in the short-duration, high-amplitude aerodynamic forces that occur when rotor-blade tips slice through or near to blade-tip vortices that remain in the vicinity of the following blades.

Figure 1 schematically illustrates how more or less BVI noise is generated during either of two typical flight maneuvers of a helicopter. In forward level flight, the plane of the rotor is tilted slightly downward in the front to provide the forward thrust needed to overcome rearward drag. Because of the combined effects

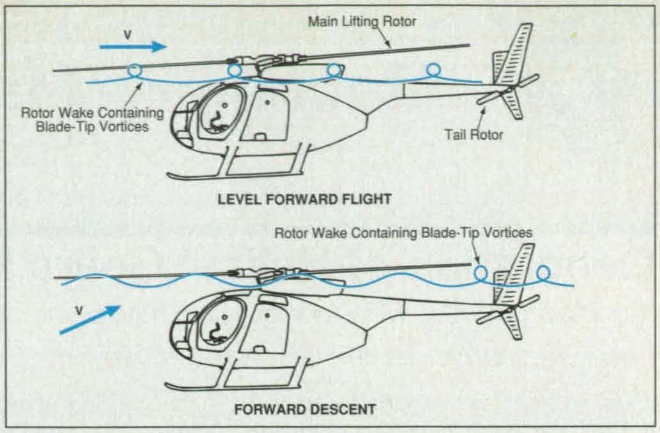



Figure 1. **Vortices Shed by the Tips** of the blades of the main lifting rotor are swept away during forward level flight, but they remain in the vicinity of the rotor during forward descent. As a result, BVI noise is more severe during forward descent.

of this tilt, of the rearward free-stream airflow (characterized by velocity **V**) relative to the helicopter, and of the downward flow induced by the motion of the rotor, the blade-tip vortices are swept down and rearward from the rotor and, as a result, BVI noise is not severe. However, during steady descent, **V** includes an upward component that opposes the downward motion of the blade-tip vortices; as a result, the blade-tip vortices remain in the vicinity of the rotor, giving rise to severe BVI noise.

Thus, to minimize BVI noise, it is desirable to maximize the flow through the plane of the rotor so that each following blade encounters as little as possible of the airflow disturbance generated by the preceding blade(s). For this purpose, the net flow through the plane of the rotor could be downward as in forward level flight or it could be upward as in the autogyro mode of operation (as in steep descent under low or no power). Each of the proposed mechanisms would alter the balance of forward and rearward forces in such a way that the main lifting rotor would have to be tilted more to obtain the desired balance of forces during the maneuver in question. The increase in tilt would cause an increase in flow through the plane of the rotor, as desired to sweep away the blade-tip vortices.

Figure 2 (facing page) shows two examples of the proposed mechanisms. In the case illustrated on the left, a helicopter would be equipped with two airfoils that would extend out sideways from the fuselage and could be rotated about their common horizontal axis. During forward level flight, the airfoils would be oriented in a horizontal plane, so that they would act as small wings, augmenting lift. Under conditions that tend to produce BVI noise (for example, during descent in forward flight), these airfoils could be turned into a vertical plane to generate drag, making it necessary to tilt the main lifting rotor more to oppose the drag.

In the case illustrated on the right, the helicopter would be equipped with ducted fans, which would provide controlled forward or rearward thrust, according to the balance of forces needed for the required tilt of the main lifting rotor. The thrust could be rearward like drag (for shedding vortices downward as in forward, level flight), or it could be forward (for shedding vortices upward as in the autogyro mode).

*This work was done by Fredric H. Schmitz of* **Ames Research Center.** *For further information,* ***write in 14*** *on the TSP Request Card.*

*This invention has been patented by NASA (U.S. Patent No. 5,437,419). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-13378.*

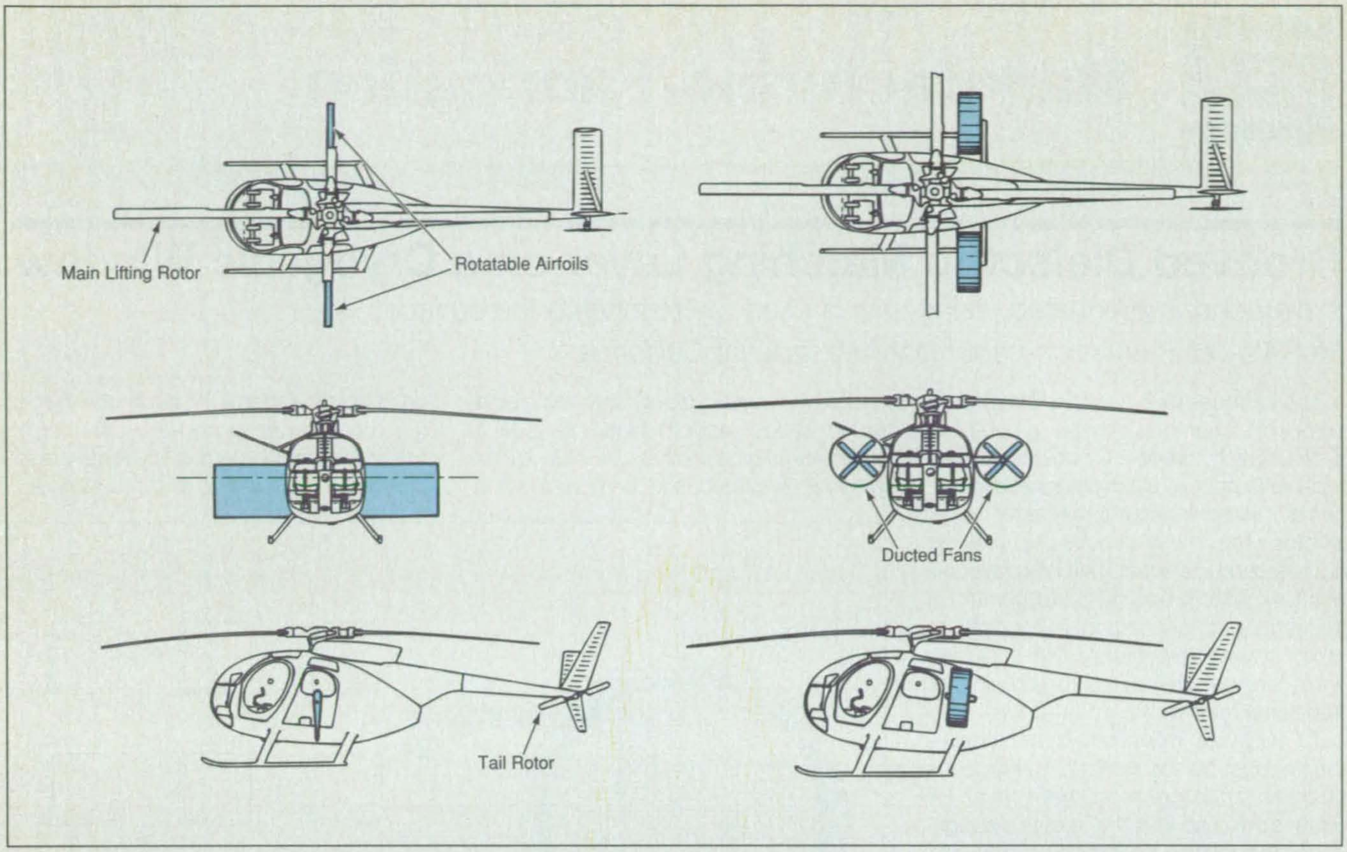



Figure 2. **Helicopters Would Be Equipped** with mechanisms to alter the balance of forward and rearward forces to change the tilt of the main lifting rotor in such a way as to reduce BVI noise.

## Grooved Dielectric Matching Layer on a Cryogenic Window

A diamond-impregnated dicing saw is used to crosshatch the surface.

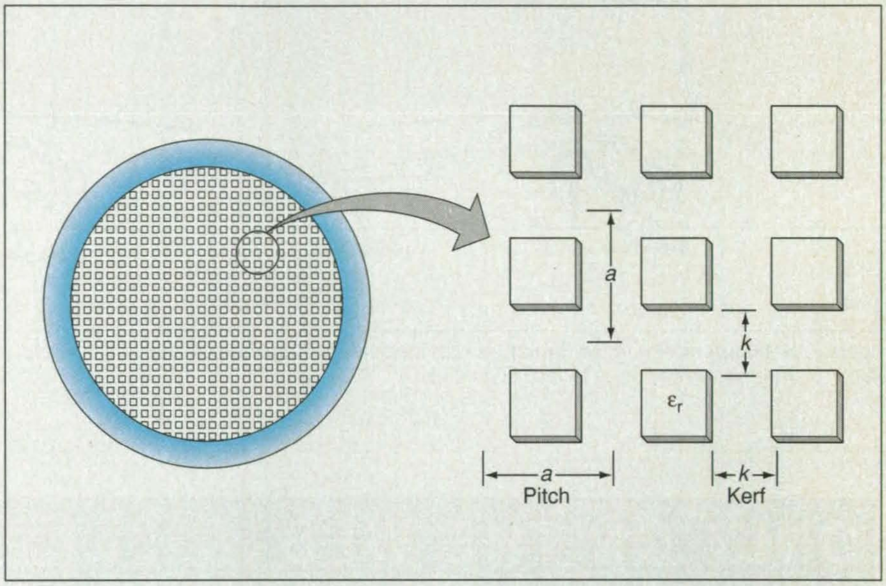
*NASA's Jet Propulsion Laboratory, Pasadena, California*

The surfaces of a quartz window on a cryogenic chamber can be grooved in a crosshatch, wafflelike pattern to minimize reflection of electromagnetic radiation at millimeter and submillimeter wavelengths. The use of grooves to simulate antireflection dielectric matching layers is not new: what is new is the application of the concept to quartz and, in principle, to other crystalline materials like sapphire, which are not well-suited to grooving by traditional means.

To minimize reflection, three requirements must be satisfied: (1) The grooves and the lands between them must be dimensioned so that the spatial average, $\varepsilon_m$, of the relative permittivity of the surface layer defined by the grooves is $\varepsilon_r^{1/2}$, where $\varepsilon_r$ is the permittivity of the quartz or other material. (2) The depth of the grooves must be a quarter wavelength or an odd integer multiple of a quarter wavelength of the electromagnetic radiation in the simulated antireflection medium; that is $\lambda_0/4\varepsilon_m$, where $\lambda_0$ is the wavelength in free space. (3) The distance between grooves must be less than a quarter wavelength to prevent a diffractive contribution of a large reflection at some particular diffraction angle.

To prepare for grooving, the large parallel surfaces of the window are ground until electrically smooth. To provide for sealing into the cryogenic chamber, a relief ring with a depth slightly deeper than the planned depth of the grooves is ground around the edge of the window. The window is then mounted on a silicon wafer, and a high-speed dicing saw with a diamond-loaded resinoid blade is used to slice parallel grooves into one surface. The window is rotated and a second set of grooves is sawed perpendicular to the first set (see figure). Then the window is flipped over and a second crosshatched pattern is cut on the opposite face, oriented 45° with respect to the first pattern to minimize interactions between the patterns.

The saw kerf, $k$, must be taken into account in calculating the pitch, $a$, of the crosshatch pattern. If, as in the figure, the grooves are to be no wider than $k$, then the average-permittivity requirement dictates the choice of pitch; namely, $a = k(\varepsilon_r^{1/2} + 1)^{1/2} / [(\varepsilon_r^{1/2} + 1)^{1/2} - 1]$. In the case of quartz, $\varepsilon_r = 3.8$, and the equation yields $2.394k$.




**Grooves Cut by a Saw** simulate a solid antireflection layer of permittivity intermediate between that of air and that of the underlying solid window material. For a frequency of 230 GHz and a quartz window, the depth of grooves should be 230 µm and if the grooves are 75 µm wide, then they should be spaced at intervals of $a$ = 180 µm.

*This work was done by Peter H. Siegel of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 46*** *on the TSP Request Card.*
*NPO-19351*

## Atomic-Oxygen Treatment To Obtain Nonstick Polymer Surfaces

Monatomic oxygen in a plasma attacks the surfaces nonuniformly, causing roughening.

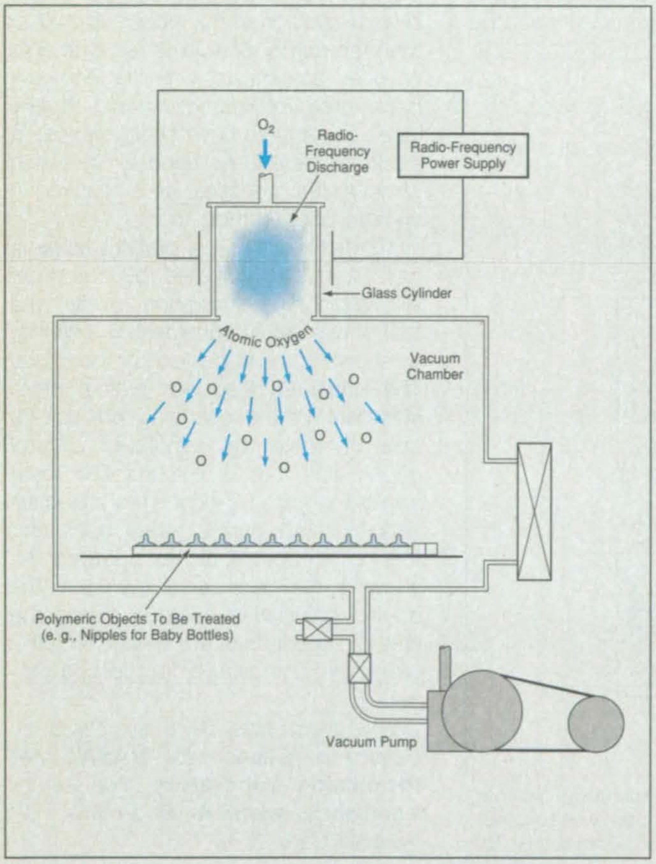
*Lewis Research Center, Cleveland, Ohio*

A simple atomic-oxygen treatment has been found to microscopically roughen smooth surfaces of polymers sufficiently to prevent sticking. Smooth surfaces of some polymeric objects (e.g., rubber food-dispensing products, packaging materials, solar-array blankets, and thermal-control polymers) tend to stick to each other, and this sticking is usually undesirable. Roughening has been found to reduce both the cohesive forces of sticking and the coefficients of friction between the surfaces in contact with each other.

Other techniques for roughening to

prevent sticking include chemical and mechanical alteration of surfaces. Chemical alteration can involve the use of harmful chemicals, while mechanical texturing is difficult to perform on thin polymeric films. Roughening can be effected by use of abrasive particles, but some of the particles can become lodged in the roughened polymers, where they can give rise to undesired effects. In contrast, the atomic-oxygen treatment usually involves no hazardous chemicals, and does not put solid contaminants into the treated surfaces, and the exhaust products of this treatment are gaseous oxides of hydrocarbons, which exert minimal adverse environmental effects.

In atomic-oxygen treatment by the present technique, the surfaces to be treated are exposed to an oxygen or air plasma (see figure). The pressure of the air or oxygen atmosphere used to form the plasma lies between 70 and 600 millitorr (between 9 and 80 Pa). The plasma can be generated by a radio-frequency discharge, dc glow discharge, microwaves, electron cyclotron resonance, or other means. Monatomic oxygen formed in the plasma arrives approximately isotropically on all exposed surfaces, oxidizing the polymer in a process that is spatially nonuniform on a microscopic scale and results in the desired roughening.




**Polymeric Objects** are roughened by exposure to a plasma that contains monatomic oxygen.

Alternatively, the plasma can contain silane or tetrafluoroethylene to provide alternative surface chemistries through either a simultaneous erosion and deposition process or through a sequential erosion-thinned deposition process to obtain surfaces with other nonsticking and/or hydrophobic properties.

*This work was done by Bruce A. Banks of* **Lewis Research Center.** *For further information,* ***write in 44*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-15796.*

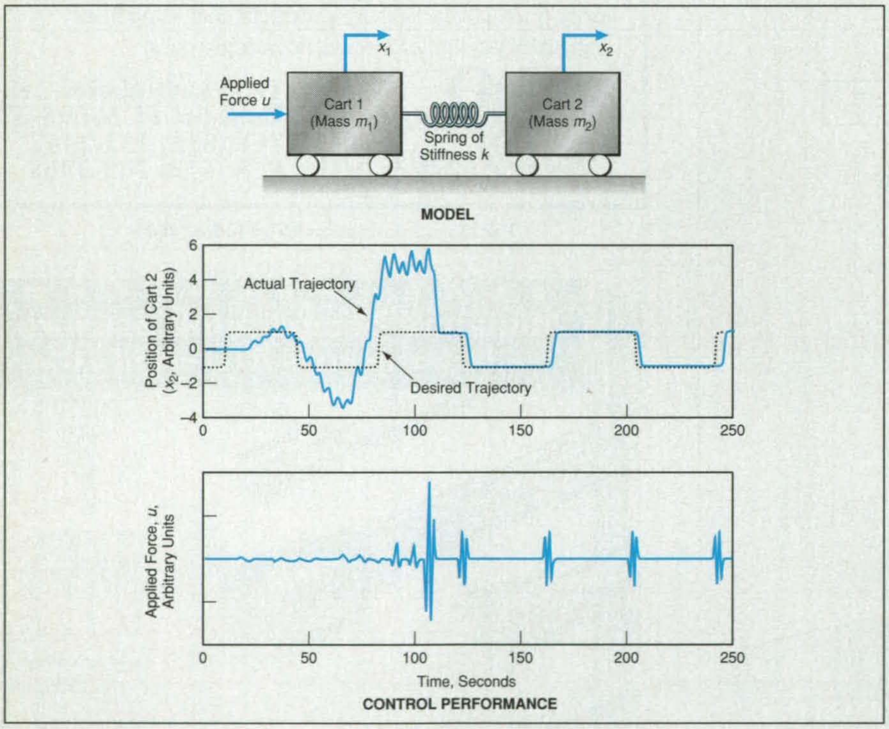
# Mathematics and Information Sciences

## Stable Adaptive Control Using Only Plant-Order Knowledge

This scheme uses the smallest amount of prior knowledge ever required for adaptive control.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

An improved adaptive feedback-control scheme provides for accurate control of a plant (a dynamic subsystem), even when the dynamics of the plant are not well known in advance and/or change rapidly. Like other adaptive-control schemes, this one involves active learning of a mathematical model of the dynamics during operation, which is used to adjust control gains so that the overall behavior of the system that comprises the plant and the feedback control subsystem converges to a specified trajectory. The advantage of the present scheme is that it requires the smallest amount of *a priori* knowledge ever required by an adaptive-control scheme: the only thing that one needs to know to design the control system is the order of the mathematical model of the dynamics of the plant.




**Two Carts Connected by a Spring** were mathematically modeled in a computer simulation to demonstrate the feasibility of the adaptive-control concept. The control objective was to generate the force, *u*, needed to move cart 2 back and forth to follow a square-wave trajectory. The actual trajectory converged to the desired trajectory at about 120 seconds into the simulation.

The present scheme is similar to prior adaptive-control schemes except that it involves the use of the recursive least-squares (RLS) algorithm rather than normalized projection, and tuning is based on minimization of the input error rather than the output error. The requirements of prior schemes for partial Markov-parameter information and Cauchy index constraints have been relaxed. In addition, there is no need for inversion of coefficient matrices, as is required in another prior method.

The feasibility of the present scheme has been demonstrated by computer simulation. The simulation model was that of two carts connected by a spring, as shown in the upper part of the figure. The simulated feedback was a measurement of the changing position of cart 2, while the simulated control action was that of a controlled force applied to cart 1. The control objective was to make cart 2 move back and forth in a trapezoidal-wave pattern. As shown in the lower part of the figure, the control gains were learned during the first 120 seconds of the simulation, after which cart 2 moved in the desired pattern.

*This work was done by David S. Bayard of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 9*** *on the TSP Request Card. NPO-19517*

## Advanced Display System for Monitoring Multiple Data Streams

Data are abstracted and presented in a graphical format that facilitates evaluation.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The Cyberspace Data Monitoring System is a developmental system of computing hardware and advanced software for graphical display of large amounts of information in real time. Originally intended for use in monitoring telemetric data from spacecraft, the system should be adaptable to monitoring other equipment systems like power plants, factories, and the like. In an alternative to the conventional text-based approach to display of data, this system conveys

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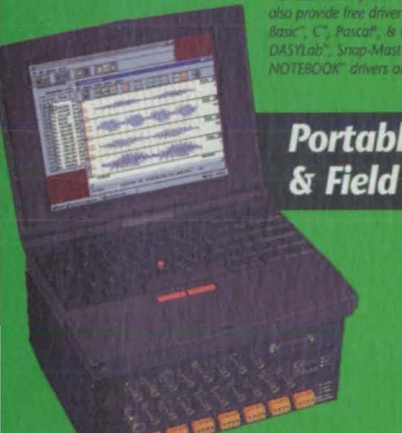

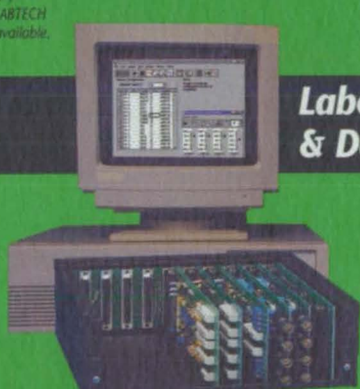

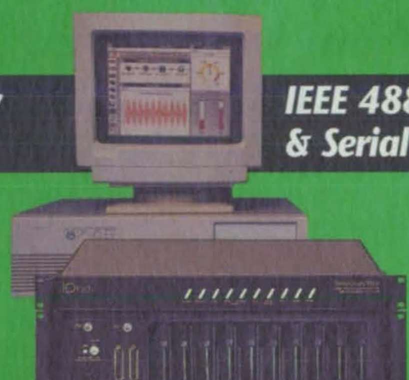

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IOtech, Inc. ■ 25971 Cannon Road ■ Cleveland, Ohio 44146 ■ 216 439-4091 ■ Fax: 216 439-4093 ■ http://www.iotech.com information through abstraction of data, using the combination of color, shape, motion, and position. The system represents data in a three-dimensional-appearing graphical video display that enables the user to view and absorb large quantities of information at a glance. This approach to abstraction and display greatly simplifies the task of a human technician charged with assessing the status of the equipment to be monitored.

The design of this system capitalizes on many of the lessons learned in prior real-time monitoring systems with regard to capabilities offered, architecture, and approaches to implementation. The implementation of the Cyberspace Data Monitoring System is highly generic, enabling the use of it for displaying information from a wide variety of simultaneous data streams. The architecture of the system is modular, and the modules of the system can be distributed over a network, if desired. Characteristics that are incorporated into the displays generated by this system include time, abstraction of data (in space), sound, distance, and navigation (travel). Data parameters from multiple sources are mapped into such display attributes as color, shape, size, position, and movement to enable immediate visual assessment of large quantities of data. Multiple systems of equipment or missions can be monitored simultaneously, and related data parameters can be grouped (and regrouped) logically in space. Changes in values, statuses, and trends are reflected in the displays. Additional detailed information specific to a parameter is readily accessible on a "point-and-click" basis.

The start-up display of the Cyberspace Data Monitoring System application program consists of two windows. One of these is a large main window, in which data (for example, from telemetry) are displayed in graphical form. The user navigates through three-dimensional cyberspace by use of a mouse or a space-ball to view the data from whatever perspective is desired. The main window includes a white grid divided into rows and columns, with rows corresponding to different sources of data (spacecraft missions in the original intended application), and columns corresponding to subgroups of data from within each source. The other, smaller window provides an overview; it keeps the user informed of alarm conditions that occur anywhere within the cyberspace world. In addition, it enables the user to know the location of the current viewpoint within the main window, as denoted by a green dot that tells the user, "You are here."

Anomalous or alarm conditions — values of parameters outside allowable limits — are immediately visible through colors and positions of graphical symbols that represent the parameters. Trend alarms, based on rates of change of parameters, are also generated. If, for example, the rate of change of a parameter exceeds some predefined limit over a predefined period of time, then a trend alarm is given via spinning or flashing of the graphical symbol for the parameter. In addition, an audible message in synthetic speech identifies the parameter, and describes the nature (limit or trend) and severity of the alarm. To find out even more information about the parameter(s) relevant to an alarm, the user can left-mouse click on the graphical symbol(s) for the parameter(s) to pop up a table containing textual information on the parameter and all other parameters in the same group. Some of the information in the table is the same as what has been traditionally available in text-based displays: this includes the names of the parameters, the time of last update, the engineering unit value or data number, and type of alarm. Other information available in this table is related to new types of alarms associated with various types of trend analysis.

The Cyberspace Data Monitoring System can also be used for off-line or non-real-time analysis. Historical data files can be replayed over time, and trend data that had been saved in a data base can be displayed. Other features enable the display of conventional plots or trend data, suppression of nominal


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parameter values, suppression of alarm notification for user-specified time intervals, and movement of data objects to any grid-square location chosen by the user.

*This work was done by Ursula M. Schwuttke, Robert Angelino, and Barbara Anderson of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 7*** *on the TSP Request Card.*

*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:*

*Larry Gilbert, Director*
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*Refer to NPO-19630, volume and number of this* NASA Tech Briefs *issue, and the page number.*

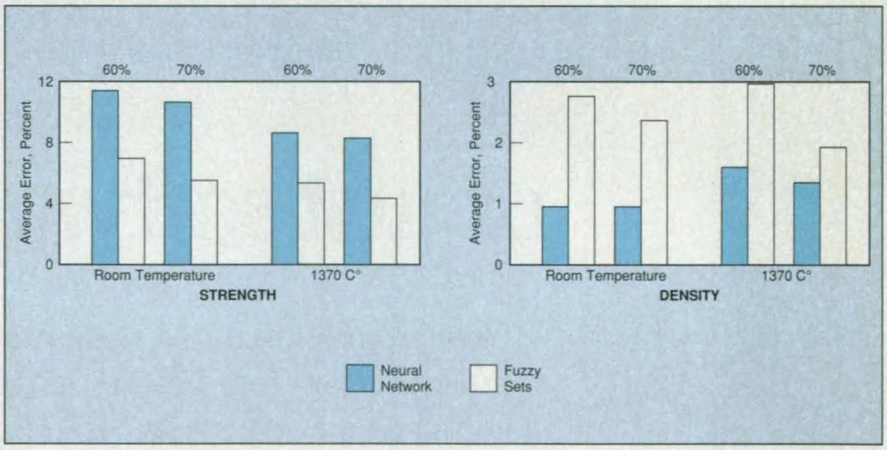
# Neural Networks and Fuzzy Sets Predict Properties of $Si_3N_4$

This approach could, presumably, be followed to optimize a variety of products and control functions.

*Lewis Research Center, Cleveland, Ohio*

Neural-network and fuzzy-set mathematical models have been found to be useful in estimating selected properties of silicon nitride ceramics that would be produced under given processing conditions. More specifically, given (1) multiple input/output sets of training data, each set consisting of experimental values of the process parameters (inputs) and the resulting values of the selected properties (outputs) and (2) input in the form of specific values of the selected process parameters for a case that one seeks to investigate without having to conduct an experiment, a mathematical model of the type in question produces (3) output in the form of approximate values of the selected properties that would be obtained if the experiment were to be conducted in that case.

The concept of using mathematical models of various degrees of sophistication to interpolate and extrapolate from known to unknown experimental conditions characterized by multiple variables with complex and uncertain relationships is not new. What is new here is the specific approach, exploiting the unique capabilities of a neural-network or a fuzzy-set model to estimate the relationships among the variables; in particular, to determine which process parameters have the greatest effect on the selected properties of interest. The objective is to use this predictive capability as a guide to optimizing processing conditions in subsequent iterations of the development cycle, thereby accelerating the development of silicon nitride ceramics and other materials. Moreover, soft computing methods, particularly fuzzy logic, can be applied to improve the performances of everyday products, like cars (in control systems for antilock brakes and automatic transmissions), cameras (control sys-




The **Average Errors** plotted are errors in strengths and densities predicted by the neural-network and fuzzy-set models as applied to test data. The percentage in each case is the percentage of input/output data sets used for training, the remainder being used for testing.

tems for autofocus and stabilization of images), washing machines (control of washing cycles according to amounts of dirt), air conditioners, and vacuum cleaners. Industrial applications beyond processing of materials may include control of elevators, control of ventilation systems for expressway tunnels, and control subsystems for voice command of helicopter maneuvers like hover, forward, right, up, and land.

Two studies were conducted to investigate the feasibility of the present approach; one study using a neural network, the other using fuzzy-set theory. The process parameters (inputs) selected for inclusion in the studies were milling time, sintering time, and pressure of the nitrogen atmosphere maintained during sintering. The selected properties of the silicon nitride product (outputs) were flexural strength and density. The reason for limiting the selection to these inputs and outputs was simply that the data available at the time were not sufficiently numerous to support a more comprehensive investigation. The input/output sets used in the investigation were those for each of (1) 273 $Si_3N_4$ modulus-of-rupture (MOR) bar specimens that were fabricated under various combinations of process parameters, then tested at room temperature and (2) 135 similar specimens that were tested at a temperature of 1,370 °C.

The neural network was of a type called "radial basis function" (RBF) and a method called "nodes-at-data-points" was used to train it. One of the distinguishing features of an RBF neural network is that it requires less training time than do neural networks of other types because it operates with a combination of self-organization and supervised learning. The nodes of its hidden layer(s) are centered at the training data points (or some subset of those points), and each node responds only to an input close to its center. In the study, the subset of training data points was selected by an orthogonal-least-squares reduction algorithm, and the neurons in the output layer were trained by a gradient-descent rule.

In the fuzzy-set study, a generalized mean operator and Hamming distance were utilized to build a fuzzy predictive model. Input and output fuzzy sets were defined, different fuzzy sets were formed for the room temperature and 1,370 °C, the grades of memberships were normalized elementwise, and the normalization was repeated for every step of prediction. The resulting membership grades were combined in a generalized mean operation to produce the resulting fuzzy sets. A measure similar to Hamming distance was used to calculate the differences between the actual and generalized fuzzy sets of input parameters.

In one of two parts of each study, 70 percent of the input/output data sets were pseudorandomly assigned to training and 30 percent to testing. In the other part of each study, the percentages were 60 and 40, respectively. The figure shows the average percentage errors in strengths and densities predicted by the neural-network and fuzzy-set models. The fuzzy sets proved superior to neural networks in capturing vague relationships between the process parameters and strengths. However, for density, which is more directly related to the process parameters, the neural network gave better results.

*This work was done by George Y. Baaklini and Alex Vary of* **Lewis Research Center** *and Krzysztof J. Cios of the University of Toledo. For further information,* ***write in 75*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16222.*

# Microencapsulation of Multiple Drugs

Several drugs can be administered simultaneously for delivery to targeted organs and tissues.

*Lyndon B. Johnson Space Center, Houston, Texas*

A method of manufacturing therapeutic drugs and enhancing their effectiveness is based on containing the drugs within microcapsules (essentially, multilayered liquid microspheres) of an improved type. The microcapsules are designed for delivery to targeted organs and tissues, where the drugs can be released directly by diffusion out of the microcapsules.

These microcapsules are formed as multilamellar, multiple-immiscible-phase structures, which can contain alternating, concentric hydrophilic and hydrophobic layers, all surrounded by a flexible, semipermeable polymeric, waxlike outer skin (see figure). Multiple drugs that are soluble in the various liquid layers can be contained in those layers. To maximize delivery of a given drug, the concentration of that drug in a particular liquid layer can be made so great that crystals of the drug are formed in that layer. The outer skin is designed to control the rate of diffusion of the drug(s) out of the microcapsule. The outer skin is also made of a material that is not recognized as foreign by the immune system, so that the microcapsule will not be destroyed by phagocytic white blood cells during transport in the blood to the target site in the body.

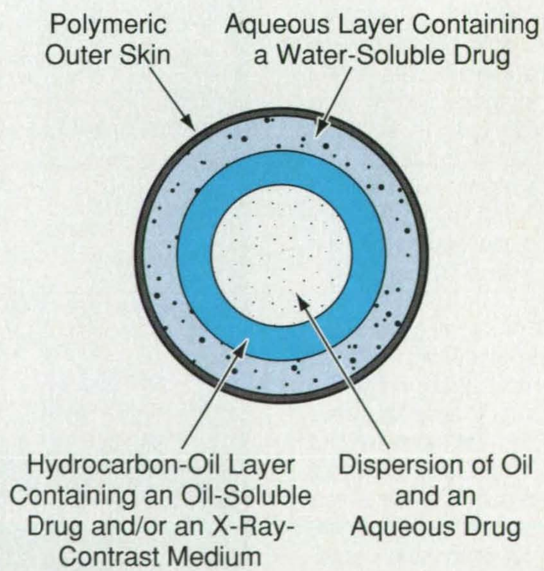
The microcapsules are formed in a process that involves codispersion of immiscible (aqueous and hydrocarbon-based) liquids. In this process, diffusion and convection driven by surface tension (solute-driven convection or Marangoni flow) leads to spontaneous formation of the multilamellar microcapsules in a single step. Essential to this process is a combination of (1) proper formulation of the ingredients, which include the drugs, aqueous and hydrocarbon solvents, oils, polymeric and low-molecular-weight cosurfactants, and water-insoluble glycerides; and (2) timed exposures of the different solutions at a quiescent immiscible interface, along with control of temperature, to take advantage of both positive and negative surface energies at interfaces between immiscible liquids. The net effect is something like a spontaneous emulsification in which the microcapsules form in a single step, without need for the stirring or solvent-evaporation steps that are needed in conventional manufacture of multilamellar microspheres.

Microcapsules can be administered to a patient by injection. The outer diameter of the microcapsules is chosen to suit the injection mode: 1 to 5 μm for intravenous, 100 to 300 μm for intra-arterial, and >200 μm for intraperitoneal. The microcapsules with diameters from 0.5 to 10 μm can be made for inhalation and deposition in the lungs.

Multiple-drug microcapsules can be designed specifically for treatment of tumors. For example, they can be used to deliver first a cytotoxic drug to kill tumor cells, then later a second drug will be released to enhance the patient's immune response to the tumor. A radiocontrast medium, such as iodinated poppy-seed oil (IPO) can be coencapsulated in the same microcapsule to enable a radiologist to monitor the accumulation in the blood vessels of vascular tumors. This confirms that adequate numbers of microcapsules (carrying cytotoxic drugs) actually reach the target tumor. Selected hydrophobic antibodies can be attached to the outer skins of the capsules to bind the microcapsules to tumor or other target cells while the encapsulated drugs diffuse out, thereby maximizing the dosage where it is needed. Multiple-drug microcapsules can deliver combinations of drugs to tumors in sites, like those in the brain, that are difficult to reach. They can provide antibiotics and immune-system stimulants to deep infections. For treatment of blood clots, they can deliver multiple, synergistic thrombolytic enzymes that would ordinarily not survive passage through the blood stream.

*This work was done by Dennis R. Morrison of* **Johnson Space Center** *and Benjamin Mosier of the Institute for Research, Inc. For further information,* ***write in 56*** *on the TSP Request Card.*

*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; (713) 483-4871. Refer to MSC-22489.*




**Concentric Layers of a Microcapsule** can contain different drugs and ancillary chemicals. A drug that must be dissolved in an oil-based medium (which patients do not tolerate well in direct injection) can be administered in such a microcapsule.

## Heaterstat™ Sensorless Temperature Controller

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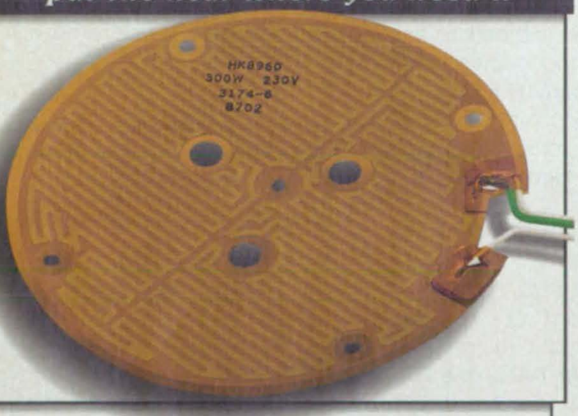

Flexible etched-foil heaters • Odd shapes, profiled or multiple elements • Efficient heat transfer: Up to 110 W/in$^2$ • 200°C polyimide, 235°C rubber, 600°C mica, 120°C transparent insulations • Optional sensors & controllers

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Thin, flexible resistance temperature detectors • Wire wound or thin-film • Pt, Cu, Ni, Ni-Fe curves • 0.1 second time response • Rugged laminated construction • -200 to 220°C range • Many sizes & styles in stock

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# Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs).

## Electronic Components and Circuits

### Ferroelectric Liquid Crystal Three-Color Filter

A detailed report describes the development of a liquid-crystal flat-panel display device with color capabilities. The device is intended for use aboard spacecraft, where it would be required to consume little power, yet be readable when viewed under intense ambient light. The development effort included a theoretical and experimental investigation of a novel color filter that includes a fast-switching, surface stabilized ferroelectric liquid-crystal device. Commercial applications are discussed.

*This work was done by Hugh Masterson, Mark Handschy, and L. Stuart III of Displaytech, Inc., for* **Johnson Space Center**. *To obtain a copy of the report, "Ferroelectric Liquid Crystal Three-Color Filter,"* ***write in 67*** *on the TSP Request Card.*

*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:*

*Mr. Mark Handschy, President*
*Displaytech, Inc.*
*2200 Central Avenue*
*Boulder, CO 80301*
*(303) 449-8933*

*Refer to MSC-21746, volume and number of this* NASA Tech Briefs *issue, and the page number.*

## Physical Sciences

### Painting Analyzed by Microscopy and X-Ray Spectrometry

A report describes how a small sample of the oil painting "Biglin Brothers Turning the Stake" made by Thomas Eakins in 1873 was analyzed by use of optical and electron microscopy and x-ray spectrometry. The general approach was to identify layers in the sample, characterize the compositions, and identify selected pigment particles within the layers.

*This work was done by James W. Smith of Cleveland State University and Todd A. Leonhardt of NYMA for* **Lewis Research Center.** *To obtain a copy of the report, "SEM Characterization of a Cross-sectional Paint Fragment Taken from an Oil Painting by Thomas Eakins,"* ***write in 80*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16019.*

### Applications of Thin-Film Thermocouples

A report presents information on thermocouples. The thermocouple metals in these devices are platinum and an alloy of 87 percent platinum with 13 percent rhodium. A thermocouple is made by sputtering films of these metals to thicknesses of a few microns onto an electrically insulating ceramic substrate or onto a thin, electrically insulating ceramic film on an electrically conductive substrate. The report discusses fabrication and tests of these thermocouples, with emphasis on the characteristics that make these thermocouples potentially useful for measuring surface temperatures in advanced, high-temperature engines.

*This work was done by Lisa C. Martin and Raymond Holanda of* **Lewis Research Center**. *To obtain a copy of the report, "Applications of Thin Film Thermocouples for Surface Temperature Measurement,"* ***write in 100*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16306.*

### Heat Fluxes Through Seams in MLI Blankets

A report discusses thermal-vacuum experiments that were directed toward quantifying the undesired flows of heat through multilayer insulating (MLI) blankets in the vicinities of the seams. The thermal-vacuum apparatus used in the experiments was the one described in "Measuring Effective Emittances of Insulating Blankets" (NPO-19641), which appears elsewhere in this issue of *NASA Tech Briefs*. The temperature patterns revealed in the tests indicate the extent to which the pinching together of the blanket layers by stitches at the seams increases the local effective emittance; the resulting local heat flux density at a seam of a typical MLI blanket under typical vacuum test conditions is of the order of 10 times that at the middle of the blanket. This finding helps explain several unexpectedly high heat-loss situations where a large number of seams occur. It also explains the superior performance of a staggered seam, dual-layup construction which has been sometimes employed over the years.

*This work was done by Edward I. Lin of Caltech for* **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Heat Loss in the Vicinity of MLI Seams and High Performance Thermal Blankets,"* ***write in 10*** *on the TSP Request Card.*
*NPO-19640*

## Materials

### Preparation and Some Properties of n-Type $Ir_xCo_{1-x}Sb_3$

A report describes an experimental study of n-doped $Ir_xCo_{1-x}Sb_3$ solid solutions — part of a continuing investigation of the potential utility of skutterudite compounds as thermoelectric materials. [Previous results from this investigation were reported in "Synthesis of $Ir_{1-x-y}Rh_xCo_ySb_3$ Semiconductors," (NPO-19234), *NASA Tech Briefs*, Vol. 18, No. 9, (September 1994), page 94, "High-Performance Thermoelectric Semiconductors," (NPO-19233), *NASA Tech Briefs*, Vol. 18, No. 12, (December 1994) page 52, and "Two Potentially Useful Ternary Skutterudite Compounds," which appears earlier in this issue. (NPO-19409)

*This work was done by Thierry Caillat, Camillo Allevato, Jean-Pierre Fleurial, and Alex Borshchevsky of Caltech for* **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Preparation and Some Properties of N-Type $Ir_xCo_{1-x}Sb_3$ Solid Solutions,"* ***write in 27*** *on the TSP Request Card.*
*NPO-19852*

## Depositing Pt on $Al_2O_3$ Fibers From a Guanidine-Based Solution

A report presents information on the use of guanidine and its derivatives in the deposition of platinum on alumina fibers, as an example of similar depositions of platinum and other precious metals on materials that are difficult to coat. The report briefly discusses the history of metal-organic deposition processes and the physical and chemical considerations involved in the use of guanidine to increase the adhesion of deposited metal films.

*This work was done by Lisa C. Veitch and Warren H. Phillip of* **Lewis Research Center**. *To obtain a copy of the report, "A Novel Method for Depositing Precious Metal Films on Difficult Surfaces,"* ***write in 1*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16307.*

# Mathematics and Information Sciences

## The PDS Data Model as Applied to WWW Interfaces

A paper, published in the proceedings of the 14th IEEE Symposium on Mass-Storage Systems, September 11–14, 1995, presents additional information on the Planetary Data System (PDS) data model, with emphasis on its use as a source for generating HyperText Markup Language (HTML) documents for access via the World Wide Web (WWW). [Such use of the PDS data model was described briefly in "Program Organizes Data for the Internet" (NPO-19830), which appears earlier in this issue. The PDS data model is a conceptual model for describing data and the development of software that encapsulates information about scientific data. The report presents a brief history of the PDS data model, describes the development of the software (now called "WEBCAT") for making the PDS data accessible via the WWW, describes how the PDS benefits from this accessibility, and discusses the adaptability of the software to any label with an ODL type of syntax.

*This work was done by John S. Hughes, Ann M. Bernath, Michael D. Martin, and David Bernath of Caltech for* **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Planetary Data System Web Catalog Interface Another Use of the Planetary Data System Data Model,"* ***write in 65*** *on the TSP Request Card. NPO-19667*

# Manufacturing/ Fabrication

## Details of Atomic-Oxygen Treatment of Polymer Surfaces

Two reports present further information about the concept described in "Atomic-Oxygen Treatment To Obtain Nonstick Polymer Surfaces" (LEW-15796), which appears earlier in this issue. The first report begins by stating the concept and its advantages, expanding on the information in the noted prior article. Briefly, the concept involves (a) generating monatomic oxygen in a dc, radio-frequency, microwave, or electron-cyclotron-resonance air or oxygen plasma and (b) exposing polymeric objects to the plasma so that erosion by the monatomic oxygen will produce microscopic roughness on their surfaces. The second report describes experiments on the effects of treating 33 different polymers with isotropically incident atomic oxygen.

*This work was done by Bruce A. Banks and Sharon K. Rutledge of* **Lewis Research Center,** *Curtis R. Stidham of Sverdrup Technology, Inc., Jason D. Hunt and Erin Drobotij of Ohio Aerospace Institute, and Michael R. Cales and Gidget Cantrell of Cleveland State University. To obtain copies of the reports, "Atomic Oxygen Treated Polymer Surfaces" and "Atomic Oxygen Textured Polymers,"* ***write in 42*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-15901.*

## Texture Etching of Indium Phosphide

A report presents information about texture etching of indium phosphide. The particular texture-etching technique does not involve any photolithography or masking and is based on the unique anisotropic-etching properties of single-crystal InP. The technique is used to produce irregular V-grooves on the surfaces of single-crystal InP wafers to reduce the effective reflectivities of InP-based solar photovoltaic cells, photodetectors, and other optoelectronic devices.

*This work was done by Sheila G. Bailey of* **Lewis Research Center** *and Navid S. Fatemi and Geoffrey A. Landis of Sverdrup Technology, Inc. To obtain a copy of the report, "Texturing of InP Surfaces for Device Applications,"* ***write in 49*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320.*

*Refer to LEW-16212.*

# Machinery/Automation

## Advanced Thermoelectric Refrigerator/Freezer

A report describes a proposed refrigerator/freezer that would be lined with superinsulation and in which the cooling would be provided by a thermoelectric heat pump in the door. Neither thermoelectric cooling, nor superinsulation, nor any of the other design details is novel and unique in itself, but the combination of these details is highly significant because it has potential for development of a new generation of high-performance, high-efficiency refrigerators.

*This work was done by Brian Vandellyn Park of Oceaneering Space Systems for* **Marshall Space Flight Center**. *To obtain a copy of the report, "Advanced Refrigerator/Freezer Based on Superinsulation & Thermoelectrics,"* ***write in 73*** *on the TSP Request Card. MFS-28990*

# Mechanics

## Limits of Applicability of the Large-Mass Method

A report reviews the large-mass method of analysis of vibrations of structures, focusing on the limits of applicability of the method. The large-mass method was described in "Estimating Peak Vibrational Stresses in Structures" (MFS-30090), which appears elsewhere in this issue of *NASA Tech Briefs*. Briefly, the large-mass method involves the placement of large masses at the base excitation points of a mathematical model of a vibrating structure; prescribed accelerations at the excitation points are obtained by applying, to each mass, a force equal to the product of the mass and the corresponding acceleration.

*This work was done by Lawrence K. Shen of Rockwell*

*International Corp. for* **Marshall Space Flight Center**. *To obtain a copy of the report, "Concepts and Application of the Large Mass Method in Vibration Analysis of SSME Engine Structures,"* ***write in 22*** *on the TSP Request Card.*
*MFS-30091*

## Development of Shock-Absorbing Legs for Landing Spacecraft

A report proposes the development of articulated, shock-absorbing legs that would cushion a spacecraft during a landing on Mars. Similar landing legs might also prove useful on helicopters, toys, and robots. The legs must be capable of limiting impact and frictional forces for any direction of impact, and must not redirect forces in such a way as to overturn the spacecraft.

*This work was done by Tommaso P. Rivellini and Randel A. Lindemann of Caltech for* **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "High Performance Landing Systems,"* ***write in 11*** *on the TSP Request Card. NPO-19924*

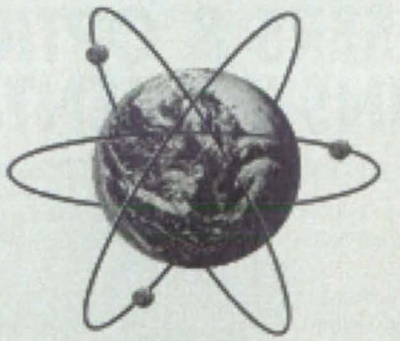
## Method for Smoothing Estimates of Orbits

A memorandum describes the development of a method for the computer inside a Global Positioning System (GPS) receiver in a spacecraft in orbit around the Earth to smooth and propagate estimates of the past, current, and future position and velocity of the spacecraft along the orbit. The method can also bridge over tracking gaps of up to several orbits, unlike conventional kinematic techniques, which are good for only a few minutes. In this method, kinematic techniques are used to establish position instantaneously, and the gravitational field of the Earth is used to establish orbital energy.

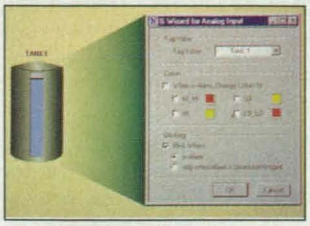
*This work was done by Courtney B. Duncan of Caltech for* **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "An Elegant Method of Embedded, First Order Orbit Smoothing,"* ***write in 53*** *on the TSP Request Card.*
*NPO-19609*





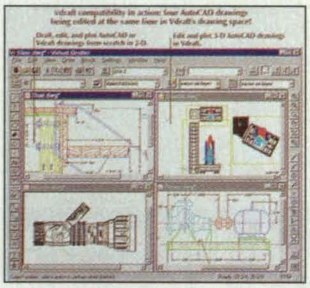



## New on Disk



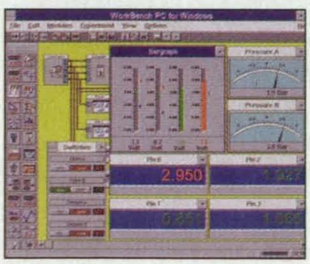
National Instruments, Austin, TX, has announced BridgeVIEW **automation system software** for building industrial-strength automation systems for process and discrete manufacturing applications. The program provides real-time process monitoring, historical trending, online configuration, and programmable logic controller connectivity. The system database updates real-time information from PLCs, analyzers, and fieldbus networks. The 32-bit Windows program is priced starting at $1295.

**For More Information Write In No. 728**



SoftSource, Bellingham, WA, has introduced Virtual Drafter AutoCAD-drawing-based **CAD software**, which allows users to work with and view multiple AutoCAD and DXF drawings simultaneously without special language or programming. Bundled with the program is a set of Internet tools that provide viewing of CAD drawings on-line. The program runs in Windows 95 and NT and sells for $495.

**For More Information Write In No. 731**

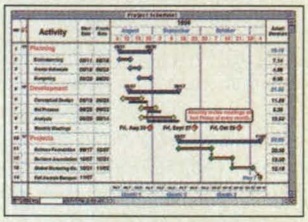


OMEGA Engineering, Stamford, CT, offers WorkBench for Windows **data acquisition software**, which allows a measuring process and control or simulation task to be set up directly on-screen in any configuration of the integrated functional components, by selecting and connecting modular elements. The software is available for $995.

**For More Information Write In No. 729**

ProFold version 4.0 **flat pattern layout software** from Applied Production, Milford, OH, works inside AutoCAD or CADKEY under DOS or Windows 3.1, 95, and NT. It unfolds and folds CAD models of sheet metal parts, compensating the geometry according to the bend allowance, which can be calculated for each bend area or may be user-specified. The results are immediately displayed in the CAD system. Users can add material thickness and arcs in bend areas to parts not created in a CAD system.

**For More Information Write In No. 722**



AEC Software, Sterling, VA, has introduced version 4.0 of FastTrack Schedule **project scheduling software** for Macintosh and Windows 3.1, NT, and 95. New features include integrated layouts, template and preference enhancements, and context-sensitive on-line help. The program uses a Gantt chart as the primary control point, representing start and finish dates along a time line. Capabilities include flexible timescales, schedule layouts, and the ability to link activities through basic commands and dialogs. The program costs $299, and includes Windows 95, NT, and 3.1 versions.

**For More Information Write In No. 721**

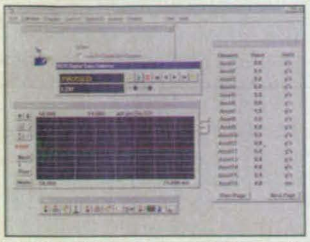
Asset InterTech, Richardson, TX, offers IEEE 1149.1 **boundary-scan diagnostic software** to aid manufacturing test personnel in pinpointing defects and salvaging non-functional boards and systems. The 32-bit program runs in Windows and Windows 95, or on VXI-based systems under Windows 95. The software can translate CAE simulation test vectors into serial test vectors that can be transmitted over the IEEE 1149.1 boundary-scan chain. Prices start at $8495.

**For More Information Write In No. 723**

Engineering Mechanics Technology, San Jose, CA, offers WiseCrack Windows-based **fracture mechanics software** for the computation of stress intensity factors, analysis of fatigue and stress-corrosion crack growth, and calculation of critical crack sizes. It contains stress intensity factor solutions for 50 geometries and fatigue crack growth characteristics for 400 materials. The program is priced at $1995.

**For More Information Write In No. 725**

# New on Disk



PI660 GRASP **data acquisition software** from Pacific Instruments, Concord, CA, records transducer measurements to disk at an aggregate rate of 500,000 samples per second. The Windows NT software programs transducer signal conditioning, calibrates each channel, and displays real-time data while recording to disk. Network support allows multi-user programming and data distribution.

**For More Information Write In No. 730**

SystemLab **virtual system prototyping software** from CPU Technology, Pleasanton, CA, provides digital system design and analysis and includes cycle-accurate software models, and virtual in-circuit emulator, logic analyzer, and clock generator. The software creates a virtual prototype with a graphical interface that allows users to compose specific views, as well as run code on the prototype's processors, observe activity on signal lines and buses, and change system characteristics. Prices start at $24,000.

**For More Information Write In No. 724**

Tripos, St. Louis, MO, has introduced Alchemy 2000 **chemistry research software,** which allows users to construct visual models of molecules in 3D on their desktop PC. The new version includes real-time graphic manipulation of molecules in 3D, property calculations with spreadsheet and graphed viewing of results, and links to other chemistry drawing and molecular programs. The price is $995; specialized modules for protein, polymer, and structure-activity research are available from $595 to $1795.

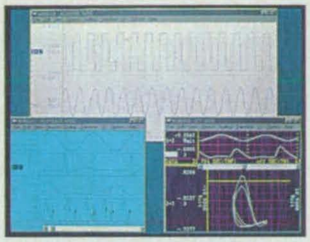
**For More Information Write In No. 732**

The Testability Director version 3.1 **testability software** from A.T.E. Solutions, Playa del Rey, CA, scores various aspects of testability for engineers to assess how testable their products will be before a design is completed. Excel™ is used as the platform, enabling importing to any spreadsheet. The software contains criteria, which are organized into sections. The program scores each criterion, calculates an overall testability score, and presents the results. The Windows-based program costs $299.50.

**For More Information Write In No. 733**

Spectral Dynamics, San Jose, CA, has released STAR System™ 5.2 **modal and structural analysis software,** which allows engineers to analyze data and access modal analysis capabilities from the STAR Gateway™ interface or popular FFT analyzers. The software supports Windows 95 and Windows NT, and is priced at $7500.

**For More Information Write In No. 734**

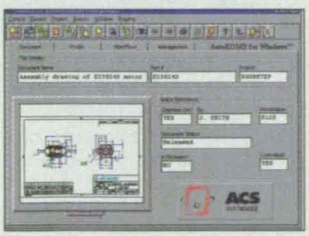


Dataq Instruments, Akron, OH, offers WinDaq/200 **data acquisition software,** which allows users to acquire, review, store, and analyze waveforms in the Windows programming environment. Features include real-time XY plotting, four data acquisition methods per channel, and support of National Instruments' LabVIEW™ software. It is compatible with Windows 3.xx and 95.

**For More Information Write In No. 736**

HyperShape® **design layout software** from Altair Computing, Troy, MI, enables users of Pro-ENGINEER® CAD/CAM software to create new designs based on fundamental structural requirements. Users can specify functional design requirements such as loads, boundary conditions, and material type. The software automatically generates an internal finite element mesh of the design space and produces a representation of the synthesized part shape in Pro-ENGINEER.

**For More Information Write In No. 735**



AutoEDMS for Windows version 4.0 **document, drawing, and image management software** from ACS Software, Lomita, CA, features network viewing support for AutoCAD R.13, MicroStation, CALS IV, and HPGL/2. The program manages documents, drawings, spreadsheets, scanned images, and faxes through user-designed screens that contain textual database information and graphical views of the files. Prices start at $895.

**For More Information Write In No. 720**



**For More Information Write In No. 435**



**For More Information Write In No. 436**

# New on the Market

## Product of the Month

LeCroy, Chestnut Ridge, NY, has introduced the LC334 and LC534 **digital storage oscilloscopes,** which feature 9" color CRT displays that allow signals to be viewed using the entire screen, 96 MHz Motorola PowerPC™ microprocessors, 64 Mb of RAM, and 2 Mb of data acquisition memory per channel that can be combined to 8 Mb on a single signal. The four-channel scopes offer acquisition memory up to 2 million points per channel and feature 500 MS/s sampling on each channel. The scopes include diagnostic, troubleshooting, and documentation tools such as measurement of over 40 signal parameters, worst-case analysis, and an enhanced math package. PCMCIA III capability is optional.

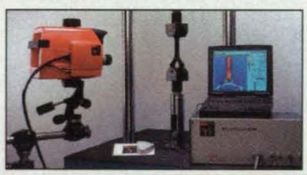
**For More Information Write In No. 710**

The Model 41 **tension/compression load cell** from Sensotec, Columbus, OH, is available in ranges from 50 to 50,000 pounds, in amplified or unamplified versions. The bonded foil strain gauge cell has non-linearity of ±0.1%, hysteresis of ±0.08%, and repeatability of ±0.03%.

**For More Information Write In No. 713**

Todd Products Corp., Brentwood, NY, has introduced the RMX 350 Series multiple output **power supplies** for configuration of OEM products requiring redundant, hot-swappable power systems. The 350-watt devices are available as a module or with a front panel for rack-mounting.

**For More Information Write In No. 716**



DeltaTherm 1000 **stress measurement system** from Stress Photonics, Madison, WI, uses infrared focal plane array technology and data acquisition and processing electronics to measure small stress-induced temperature changes in dynamically loaded engineered structures. It determines the location and severity of cracks, compares prototype designs and analyzes their reaction to loads.

**For More Information Write In No. 718**

Middex high-power **step motor drivers** from Ciro Products, Hickory, NC, are available from 40 VDC to 160 VDC with phase currents from 2 to 12 amps and resolutions from 200 to 10,000 steps per revolution. The drivers feature digital current adjustments for stand-by, boost, and run.

**For More Information Write In No. 717**

Bimba Manufacturing, Monee, IL, offers stainless steel **air cylinders** in bore sizes of 2", 2.5", and 3".The cylinders feature adjustable cushions on the rear, front, or both ends that slow cylinder speed at the end of a stroke, reducing impact. They are available in a range of stroke lengths.

**For More Information Write In No. 712**

Gould Instrument Systems, Valley View, OH, has introduced the COBRA16 **data acquisition recording system,** which provides signal monitoring, conditioning, and capture, as well as chart output and signal playback and analysis. It uses a laptop PC controller running Windows-based applications and features 8- or 16-channel models.

**For More Information Write In No. 714**

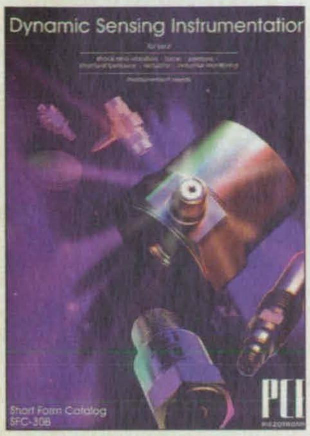
The VHB™ family of **tape products** has been introduced by 3M Industrial Tape and Specialties Division, St. Paul, MN. The tapes feature acrylic and synthetic adhesives that can be applied at 0° C, bond to low surface-energy materials, and may use a conformable foam to optimize surface contact and strength.

**For More Information Write In No. 711**

A line of low-profile **gearboxes and geared motors** from Lenze Power Transmission, Fairfield, NJ, is available in six sizes. The gearboxes transmit torques to 7700 lb.-in. and minimal backlash of 4.5 to 12 angular minutes. Motors up to 60 HP are available as drive modules.

**For More Information Write In No. 715**

# New Literature




PCB Piezotronics, Depew, NY, has released a 24-page catalog of **dynamic measurement instrumentation** products. Included are pressure, force, structural testing, and vibration sensors; multichannel accelerometers; pressure generators; and computer-programmable signal conditioners.

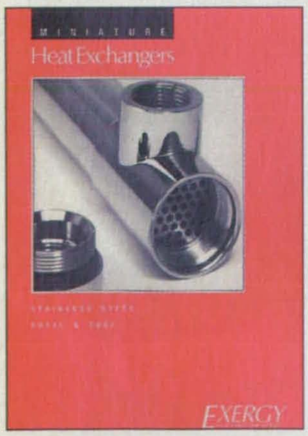
**For More Information Write In No. 700**

An eight-page catalog describing **CCD image sensors and cameras** from DALSA, Waterloo, ON, Canada, features applications of line scan, time delay and integration line scan, and area scan technologies. A chart listing camera compatibility with frame grabber/image acquisition boards is included.

**For More Information Write In No. 701**

Teknocraft, Melbourne, FL, offers a product sheet on solenoid-operated **proportional flow control valves.** The single-stage, two-way, DC signal poppet valves provide high linearity and low hysteresis.

**For More Information Write In No. 702**

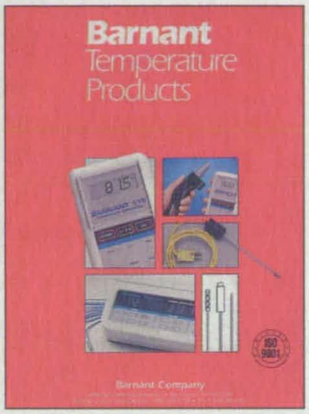



A 12-page brochure of miniature stainless steel shell and tube **heat exchangers** is available from Exergy, Hanson, MA. Pressure and temperature limits, application data, and optional mounting kits and fittings also are described.

**For More Information Write In No. 703**

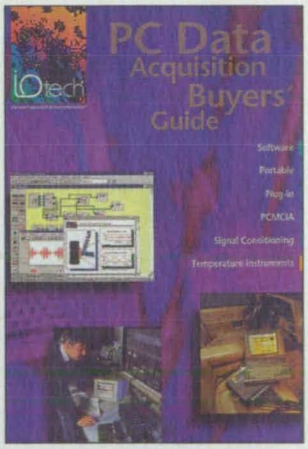
An application note and technical paper booklet on **VXIbus products** is available from Racal Instruments, Irvine, CA. An introduction to VXI, VXI-based instruments, and articles covering VXIbus system integration are included.

**For More Information Write In No. 705**




Barnant, Barrington, IL, offers a 20-page catalog describing **temperature products,** including thermocouple thermometers, infrared probes, and temperature controllers. Also featured are thermistor and intrinsically safe products, accessories, field kits, and temperature sensor design capabilities.

**For More Information Write In No. 706**




IOtech, Cleveland, OH, has released a catalog describing **PC data acquisition products,** including software, portable systems, PCMCIA cards, plug-in boards, signal conditioning equipment, and temperature and voltage instruments.

**For More Information Write In No. 704**

MicroMath Scientific Software, Salt Lake City, UT, has released a 16-page catalog of **scientific software** for Windows and DOS, including SCIENTIST® for Windows, Chemical Kinetic Library, Diffusion Library, PKAnalyst® for Windows, and resale items. Also featured is information available on the company's web site.

**For More Information Write In No. 707**

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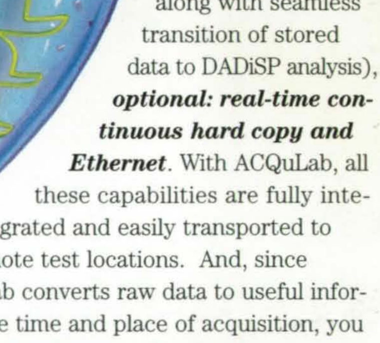

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